ON FINDING

THE

LATITUDE AND LONGITUDE

IN CLOUDY WEATHER

AND AT OTHER TIMES.

BY

A. C. JOHNSON, R.N.

AUTHOR OF

"HOW TO FIND THE TIME AT SEA IN LESS THAN A MINUTE," &c.

THIRTY-SIXTH EDITION.

WITH NEW TIME-AZIMUTH AND EX-MERIDIAN TABLES.

ALSO TABLES FOR FINDING

THE LONGITUDE BY CHRONOMETER, &c.

(Supplied to H. M. Ships by Admiralty Order.)

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PREFACE TO THE 32ND EDITION.

The publication of another edition of this little book affords the Author the opportunity of again expressing his thanks to the numerous officers of the Royal Navy and Mercantile Marine who have from time to time favoured him with their opinions as to the value and utility of the following methods. Among those who, in the past, have so favoured him, he would gratefully mention the late Captain Lecky, R.N.R., for the prominence which he gave them in his "*Wrinkles*"; also Captain Blackburne, of the P. and O. Service; and Captain Owen, of the Union Line; and the late Hydrographer of the Navy, by whom this book was ordered to be supplied to H. M. Ships. The accompanying extracts will suffice to show the estimation in which it is held by practical navigators:—The senior navigating officer of the squadron employed in towing out the Great Bermuda Dock says—"During the passage I seldom got the sun at noon, and, had it not been for your Double Chronometer Method, I don't know what might have been the consequences, for we had hardly taken in our moorings when it came on to blow a most violent norther," &c. And an officer commanding a merchant vessel writes—"My ship and another sailed at the same time from Liverpool, bound to Matamoras; the weather being cloudy, I used your method, and arrived four days before the other ship, although she was a faster sailer; and on my return from Pernambuco I did not see the sun at noon for eleven days previously to making Cape Clear, but, trusting to my Double Chronometer, sighted the Cape just when I expected."

This book has also been translated into French by Lieut. O. V. de Jassaud; German, by Theodor Lüning of the Royal School of Navigation, Flensburg; Italian, by Captain Guarianti of the Italian Hydrographic Office, and Spanish by Captain Garcià Núñez of Santander, since awarded by the King of Spain the Royal Order of Naval Merit. It is also well known to American and Japanese Navigators, and a Turkish Version by Commander Mehmed Ali Bey, H.I.O.S., "Messoudieh," has recently been published.

Dartmouth, *1909.*

Note.—A Danish Translation was made by Robert Lundgren in 1912. A Russian version is in course of preparation (1917) by Captain V. Androunin, Transport "Mercury."

OPINIONS OF THE PRESS, &c.

Shipping and Mercantile Gazette.

"It is expressed in such clear words, and the tables are so intelligible that they may be quickly understood by students. To the shipmaster this cheap and practical work, of a few pages, will be found a valuable assistant at sea."

United Service Gazette.

"Any simplification and condensation of the methods of finding the longitude at sea are very great desiderata. Mr. Johnson has conferred a great benefit on the nautical world, and deserves the gratitude of every navigator. The rules are *simple* and concise."

From "Modern Navigation," by CAPTAIN HENRY TAYLOR,
San Francisco, U.S.A., 1904.

" . . . And as a final word we wish to state that there is no method in existence to-day of so much value to navigators as Johnson's."

The Author has much pleasure in publishing one of many spontaneous tributes to the usefulness of this little book; the more so, as it exactly describes the objects it is intended to accomplish :—

"I cannot refrain from expressing my admiration for your little (?) work on 'Finding the Latitude and Longitude in Cloudy Weather.' This is not in any way due to the problem being new to me, as I have used it constantly for the last ten years. Possibly a rather cloudy and misty passage has emboldened an often-felt desire to tell you that the longer I know our little friend, the more I feel thankful for its tranquilising effects, especially after a spell of S.W. winds in the 'Bay.' Only those in command can realise the comfort and pleasurable satisfaction it gives. If you will kindly accept this assurance from one who is repeatedly deriving consolation from its use, it will gratify a long-felt wish," &c.

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ON

CORRECTING THE LONGITUDE

FOR AN ERROR IN THE LATITUDE,

AND ON

FINDING THE LONGITUDE SIMULTANEOUSLY

WITH THE LATITUDE AT NOON.

It is frequently necessary for the officer entrusted with the navigation of a ship to calculate his longitude as soon as his sights are taken, in order to obtain without delay as close an approximation to the actual place of the ship as may be possible: but should only the latitude by dead reckoning be available, his result will be erroneous, unless, which is seldom the case, the dead reckoning be correct. Let us suppose that the navigator, on taking the sun at or near noon, has discovered that the latitude he employed is a certain number of miles in error; he must then re-calculate his longitude with the corrected latitude, unless by any means he can correct that already found by making an allowance for the error in his latitude. To enable him to do this is the object of what follows:—

(I.) *To find the Correction.*

From Table II. take the number corresponding to the latitude and bearing of the sun at the time of observation: this, multiplied by the correction for the latitude, will be the correction required.

(II.) *To name the Correction.*

Under the sun's bearing at the time of the observation write the opposite bearing, and suppose the letters to be connected diagonally, then that connected with the name of the correction for latitude will be the name of the correction for the longitude.

Thus, if the correction for the latitude were 10′ N. and the sun's bearing S. 60° W.,

We should write down S.W.

And under it N.E.

Then as the letter which stands diametrically opposite to N. (the name of the corr. for lat.) is W., the correction for longitude has to be allowed towards the West: and so on in other cases.

The bearings may be taken from an Azimuth Table, or they may be easily found by means of Table I. In every case they are to be considered as less than 90°; so that when the Tabular bearings exceed 90°, we must subtract them from 180°, and reckon them from the opposite point of the compass; thus, S. 120° W. would be N. 60° W., and so on.

The correction may also be found by the Traverse Table, as follows:—

Enter the Table with the complement of the bearing as a course and the correction for the latitude as a diff. lat., and take out the corresponding departure. This converted into longitude in the usual way will be the correction required, and is to be applied as directed above.

Example I.

June 1.—At 9 a.m., in lat. D.R. 52° 10′ N., when the sun bore S. 48° E., sights for longitude by chronometer placed the ship in 41° 16′ 45″ W. At noon the above latitude was found to be 20 miles too far to the southward, and therefore the correction is 20′ N. To find the true longitude—

(Tab. II.) Lat. 52°, and bearing 48°, give 1′.46; this number multiplied by 20 is the correction required.

Approximate long..........	41°	16′	45″	W.	S.	E.
Corr. .... 1′·46 × 20 =		29	12	E.	N.	W.
True longitude at 9 a.m...	40	47	33	W.		

Here as the sun bore S. 48° E., we write down the letters S.E., and the opposite letters under them; it is then seen that as the correction for the latitude is N., that for the longitude is E.

Example II.

July 25.—The sun being obscured at noon—at 2 p.m. in lat. D. R. 40° 42′ N., when the sun bore S. 64° W., sights for longitude placed the ship in 43° 51′ 45″ E. At 9 p.m. by a star observation the above latitude was found to be 30 miles too far north the correction being accordingly 30 S. Find the true longitude.

(Tab. II.) Lat 40° and bearing 64° give 0′·64, which, multiplied by 30, is the correction required.

Approximate long.... ...	43° 51′ 45″ E.	S. W.
Corr.... ... 0′·64 × 30 =	19 12 E.	
		N. E.
True longitude at 6 p.m..	44 10 57 E.	

In this case the bearing being S. 64° W., we write down the letters S.W. and the opposite letters under them; it is then seen that as the correction for the latitude is S., that for the longitude will be E. To satisfy himself and to see what degree of dependence may be placed in the preceding rule, the navigator is recommended to put it to the test by his own observations.

To find the longitude by observation at noon simultaneously with the latitude.

Example III.

At 8 a.m. sights for longitude worked with lat. D.R. 30° 10′ N. placed the ship in 20° 12′ W., and the sun bore S. 62° E. Steaming N.W. (true) 10′ an hour, her lat. and long. *brought up to noon* by the log would be 30° 38′ N., and 20° 45′ W. But at noon the lat. by mer. alt. was found to be 30° 48′ N. Hence the correction for the above lat. was 10′ N., and the correction from Tab. II. is ·61′. Therefore we have

Approx. noon long....	20° 45′ W.	S. E.
Corr. ... ...·61 × 10′ =	6 E.	
		N. W.
True long. at noon	20 39 W.	

Another advantage of the preceding method.

When two or more men-o'-war are cruising in company, it is customary for each ship to show its latitude and longitude at about half an hour or so after noon. Any evolution that may be necessary is then executed. Now, if the preceding method were adopted, each ship could show her position *at noon*—thereby saving valuable time, and possibly avoiding danger or inconvenience.

In cloudy weather the latitude may be found very expeditiously by means of Table III., which will give quite as satisfactory results as the more voluminous tables that are used for the purpose of reducing the altitude to the meridian at sea.

The same by projection on the Chart.

Through the position of the ship, as determined by the latitude D. R., and approximate longitude by observation, draw a line at right angles to the sun's bearing; this is called the position line,* as the ship will be somewhere on it: the exact point will be where this line is cut by the parallel of the true latitude.

In cloudy weather, when the ship is approaching the land, the position line produced will show its direction; or if it runs parallel to the land will show the distance of the ship from it. Also, when in soundings, a cast of the lead will indicate approximately the place of the ship on the position line.

Examples for Practice.

Time.	Lat.	Bearing.	Cor. for Lat.	Cor. for Long.	Approx. Long.	True Long.
A.M.	50°	S. 60° E.	20′ N.	18′ E.	15° 41′ W.	15° 23′ W.
A.M.	40	S. 70 E.	10 S.	5 W.	16 20 E.	16 15 E.
A.M.	20	S. 75 E.	15 N.	4 E.	17 50 W.	17 46 W.
P.M.	60	N. 30 W.	16 S.	55 W.	40 13 W.	41 8 W.
P.M.	45	S. 55 W.	18 S.	18 E.	3 45 W.	3 27 W.
P.M.	10	N. 60 W.	25 N.	15 E.	4 45 E.	5 0 E.

As a general rule, if the observations are taken at the ordinary times, the preceding method may be relied on, even though the error in latitude should amount to half a degree or more; so that a re-calculation of the longtitude is quite unnecessary.

The longitude found by a star observation may be corrected in the same way.

* An easy way to find the direction of the position-line is to reverse the first letter of the bearing, and subtract the degrees from 90°, thus if the sun bore S. 60° E., the direction of the position-line would be N. 30° E., or S. 30° W.

DOUBLE CHRONOMETER METHOD;

OR

RULE FOR FINDING THE LATITUDE AND LONGITUDE BY TWO CHRONOMETER OBSERVATIONS.

The ship's place may not only be determined with the utmost facility and accuracy by means of this rule, but it will also be found especially useful in cloudy weather, when there is little probability of being able to get an observation at noon. Every Navigator is familiar with the mode of finding the longitude by chronometer, and many careful ones make it their practice to take two observations at an interval of about an hour and a half or two hours. Those who do so may, with very little extra trouble, easily determine their latitude as well as their longitude, and thus be independent of the meridian altitude. The great utility of this method has been proved by the experience of officers both of the Navy and of the Merchant Service; many of whom, by means of it, have made most successful passages across the Atlantic,—to and from the West Indies,—&c., when they have not been able to see the sun at noon for many days together.*

RULE.

I. Let two chronometer observations be taken at an interval of about an hour and a half or two hours,† and let the first be worked out with the lat. D.R. at the time of observation.

II. Let the lat. D.R. and long. thus obtained be corrected for the run of the ship in the interval between the observations, and let the second observation be worked with this corrected latitude. Name these longitudes (1) and (2).

III. The bearing of the sun at each observation is to be taken from an Azimuth Table.

IV. Enter Table II. with the latitude and bearings, and take from it two numbers (*a*) and (*b*), of which take the difference, or sum, according as the bearings are in the same or adjacent quarters of the compass.‡ The difference of longitude divided by this difference or sum gives the correction for the second latitude; and (*a*) and (*b*) multiplied by the correction for latitude give the corrections for the two longitudes.

* It has moreover the advantage of being equally applicable to star observations, which are daily assuming more importance in modern navigation.

† Provided that the sun's bearing has changed not less than a point and a half, or two points, if possible. *Vide* p. 14.

‡ Also, if the bearings are in *opposite* quarters, take the difference of (*a*) and (*b*).

V. *To apply the Corrections for the Longitude.*

When the observations are in the *same* or *opposite* quarter of the compass,

Allow the corrections *both* to the East, or *both* to the West

When the observations are in *adjacent* quarters of the compass,

Correct the Easterly longitude towards the West, and the Westerly longitude towards the East

in such a manner as to make the two longitudes *agree*. If they do not agree, they show that the corrections have been wrongly applied; and herein we have a valuable safeguard against error, peculiar to this method only.

VI. With either correction, and the corresponding bearing, find the name of the correction for the latitude, as in the preceding rule.

Thus, suppose the correction for either longitude to be W., and the corresponding bearing S.W.: writing the letters N.E. under the above, we see that the letter opposite to W. is N., which is, accordingly, the name for the correction for latitude (2).

Example I.

March 7, at 8 a.m., in lat. D.R. 50° 20′ N., when the sun bore S. 60° E., chronometer sights placed the ship in 20° 15′ W. She then ran S.W. 20 miles, till 10 a.m., and her latitude being at this time 50° 6′ N., a second observation placed her in 20° 56′ W., the sun's bearing being S. 40° E. It is required to find the ship's true position at the time of the second observation.

Run S.W. 20 miles gives d. lat. 14′ S., d. long. 22′ W.

Lat. (1)	50° 20′ N.	Long.	20° 15′ W.
Run	0 14 S.	Run	0 22 W.
Lat. (2)	50 6 N.	Long. (1)	20 37 W.

Bearings	(Tab. II.)	Longitudes	(a)	(b)
S. 60° E.	·90 (a)	(1) 20° 37′ W.	·90	1·85
S. 40 E.	1·85 (b)	(2) 20 56 W.	20	20
Diff.	·95	95)1900(20	18·00	37·00

Long. (1)	20° 37′ W.	(2)	20° 56′ W.	Lat. (2)	50° 6′ N.	S. E.
Correction	18 E.	Corr.	37 E.	Corr	20 N.	N. W.
Long in	20 19 W.		20 19 W.	Lat. in	50 26 N.	

The latitude of the ship is therefore 50° 26′ N., and the longitude 20° 19′ W.

If long. (2) confirms long. (1) it will be the true longitude of the ship, and show that lat. (2) is correct.*

In the above example, both bearings being in the same quarter of the compass, we take the difference of (*a*) and (*b*); and, to avoid decimals, remove the decimal point two places to the right, both in divisor and dividend; or, if preferred, proceed as directed on page 15.

Example II.

Oct. 10th, at 9 a.m. in lat. 40° N., when the sun bore S. 50° E., chronometer sights placed the ship in 20° 40′ E.; she then ran N. 60° W. 30 miles, till 2 p.m., and her latitude being at this time 40° 15′ N., a second observation placed her in 20° 26′ E., the sun's bearing being S. 30° W.: it is required to find the ship's true place at the time of the second observation.

Run N. 60° W. 30 miles gives d. lat. 15′ N., d. long. 34′ W.

Lat. (1)	40° 0′ N.	Long.	20° 40′ E.
Run	15 N.	Run	34 W.
Lat. (2)	40 15 N.	Long. (1)	20 6 E.

Bearings.	(Table II.)	Longitudes.	(*a*)	(*b*)
S. 50° E.	1·09 (*a*)	(1) 20° 6′ E.	1·09	2·26
S. 30 W.	2·26 (*b*)	(2) 20 26 E.	6	6
	Sum 3·35	335)2000(6	6·54	13·56

(1)	20° 6′ E.	(2)	20° 26′ E.	Lat. (2)	40° 15′ N.	S. E.
Cor.	6 E.	Cor.	14 W.	Cor.	6 N.	/
						N.W.
Long.	20 12 E.	Long.	20 12 E.	Lat. in	40 21 N.	

Hence the required latitude is 40° 21′ N., and long. 20° 12′ E. In this case we take the sum of (*a*) and (*b*), because the bearings are in adjacent quarters of the compass.

The same by projection on the Chart.

On the parallel of the *second* latitude lay down longitudes (1) and (2), and through these two points draw the corresponding position lines; then where they intersect will be the position of the ship at the second observation. The position lines are found as directed on page 10.

* In the same way may be found the ship's position by the altitudes of two stars. *Vide* Lecky's "*Wrinkles*," Owen's "*Stellar Navigation*," &c.

*Examples for Practice.**

Observations in the *same* quarter of the compass.
Diff. of *a* and *b*.

Lat. D.R.	Bearings.	Longitudes.	Results.
50° 0′ N.	N. 60° E. N. 85 E.	(1) 40° 18′ W. (2) 40 40 W.	50° 29′ N. 40 44 W.
48 20 N.	S. 80 E. S. 51 E.	(1) 20 15 E. (2) 19 45 E.	48 52 N. 20 23 E.

Observations in *adjacent* quarters of the compass.
Sum of *a* and *b*.

Lat. D.R.	Bearings.	Longitudes.	Results.
20° 15′ S.	N. 40° E. N. 20 W.	(1) 20° 50′ W. (2) 21 30 W.	20° 6′ S. 21 2 W.
52 30 S.	S. 80 E. N. 50 E.	(1) 2 20 W. (2) 2 40 W.	52 42 S. 2 24 W.

The following are some results of actual observations taken in lat. 50° 21′ 30″ N., and long. 3° 34′ 15″ W.:—

Interval.		Lat. used.		Lat. by Obs.			Long. by Obs.		
h.	m.	°	′	°	′	″	°	′	″
5	8	50	0 N.	50	22	0 N.	3	35	45 W.
1	13	50	0	50	21	48 N.	3	33	30 W.
1	13	50	30	50	22	0 N.	3	34	0 W.
0	26	50	0	50	22	0 N.	3	35	15 W.
0	33	50	40	50	21	18 N.	3	33	45 W.
0	33	50	0	50	21	54 N.	3	30	33 W.
0	54	50	0	50	23	0 N.	3	32	0 W.

Several of these observations were taken under unfavourable conditions as to time and weather, the change in the bearings, in some cases, being very small, whereas it should not be less than a point and a half or two points, unless the observations be exceedingly good. The more nearly the bearings are at right angles to each other, the more accurate will be the results, and, as a general rule, the best results are given when the change in the bearings exceeds the lesser bearing.

* In these examples the correction for run is supposed to have been applied as shown on pages 12 and 13.

NOTES.

1. The foregoing method is applicable not only to sun observations, which are of course to be preferred, but also to observations of two stars, or two observations of the moon or a planet, after a sufficient change of bearing. It may also be employed in the case of a sun observation taken before sunset and at an altitude of not less than 5° or 6°, and the altitude of a star taken in the evening twilight; or of the moon or a planet, whichever is most convenient. In the case of a morning observation it may be combined with a star taken before sunrise, and an observation of the sun taken an hour or two after, the proviso as regards the change of bearing being duly adhered to.

2. It will be noticed that the sum or difference of the two longitude corrections is equal to the difference of longitude. The sum when the bearings are in different quadrants, and the difference when they are in the same or opposite quadrants. This is another valuable check as regards accuracy.

CALCULATION OF POSITION BY TABLE IIA.

This table has been inserted with the object of saving the trouble of multiplying or dividing, especially when the quantities are high numbers. In division, look for the divisor under "Nr. from Table II.," and the number to be divided in the same line, then at the top of the column in which it occurs will be the quotient. Thus, suppose we have to divide 19 by ·95 as in Ex. I. p. 12, we look for ·95 under "Nr. from Table II.," and 19 in the same line, then at the top of the column we find 20′, the quotient required. In Ex. II. p. 13, we have to divide 20 by 3·35, which is the same as 10 by 1·67, which gives 6 and so on.

It will be noticed that all three corrections are found in the same column, which is a great saving of time.

N.B.—If the number in the column "Nr. from Table II." does not exactly correspond with that from Table II. take the nearest or mean as the case may be, and if the error in lat. exceeds 31′ enter with its half and double the result.

This Table may also be used to save the calculation of the "run" for a portion of an hour by entering with the speed in the upper row of figures and the time in the margin.

e.g. Speed 25 knots, to find run for 42 minutes.

In the 25′ column, on the same line as 42 minutes will be found the answer 17·5.

EXAMPLES ILLUSTRATING THE USE OF TABLE IIa.

Example I.

Bearings.	Table II.	Longitudes.
N. 60° E.	·90	(1) 40° 18′ W.
N. 85° E.	·14	(2) 40 40 W.
	Diff. ·76	D. long. 22

Long. (1) 40° 18′ W.	Long. (2) 40° 40′ W.	Lat. (2) 50° 0′ N.
Corr. 26 W.	Corr. 4 W.	Corr. 29 N.
Long. in 40 44 W.	Long. in 40 44 W.	Lat. in 50 29 N.

Corrections.

D. long.	22′ ÷ ·76 = 29′	N. E.
	29 × ·90 = 26	\
	29 × ·14 = 4	S. W.

To find the lat. corr. enter the Table with ·76 (or ·75) at the side and look for the nearest D. long. 21·7 in the same line, then at the top of the column will be found 29′.

Example II.

Bearings.	Table II.	Longitudes
S. 70° E.	·47	75° 10′ E.
S. 50° W.	1·09	74 45 E.
	Sum 1·56	D. long. 25

Long. (1) 75 10 E.	Long. (2) 74° 45′ E.	Lat. (2) 40° 20′ N.
Corr. 7½ W.	Corr. 17½ E.	Corr. 16 S.
Long. in 75 2½ E.	Long. in 75 2½ E.	Lat. in 40 04 N.

Corrections.

D long.	25′ ÷ 1·56 = 16′ * nearly	S. E.
	16 × ·47 = 7½	\
	16 × 1·09 = 17½	N. W.

Note.—If the divisor for the diff. long. exceed the limit of the Table, divide it by 2 or 3, as the case requires; also divide the diff. long. by the same number, and proceed as before.

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* Here 1·55 in the side column and 24·8 (or 25) in the same line give 16′ at the top.

TO FIND THE LONGITUDE-CORRECTION AND TIME-AZIMUTH BY TABLES I. AND II.

NOTE.—These Tables can be adapted to any latitude between 60° and 80° by means of the Supplementary Tables on page 35.

TO FIND THE TIME-AZIMUTH.

Take from Table I. the numbers for the H.A. and Lat., and for the H.A. and Dec. The sum or difference of these in the proper Latitude Column of Table II. gives the Bearing, or Azimuth, which will be found on the left-hand side of the Table.*

TO NAME THE AZIMUTH.

Mark the first number with the *opposite* name to the Lat., and the second with the *same* name as the Dec. When the names are the same, take the sum with the common name; when different take the difference with the name of the greater. This will be the point from which to reckon the Azimuth.

Exception.

When the H.A. exceeds six hours, mark the first number with the *same* name as the Lat. and proceed as before.

Examples.

1. Lat. 40° N., Dec. 20° N., H.A. 3h. 48m. E. of Mer.
   For Lat. 40° N. and H.A. 3h. 48m. we have ·54 S.
   „ Dec. 20° N. and H.A. 3h. 48m. we have ·43 N.

   Diff. ·11 S. = S. 85⅕° E. Table II.
   By calculation S. 85°·1 E.

2. Lat. 20° N., Dec. 14° S., H.A. 4h. 40m. W. of Mer.
   The above give ... ... ·13 S.
   And ·27 S.

   Sum ·40 S = S. 69⅕° W. Table II.
   By calculation S. 69°·5 W.

3. Lat. 46° N., Dec. 14° N., H.A. 6h. 40m. E. of Mer.
   For the above we have ... ... ·18 N.
   And ·26 N.

   Sum ·44 N. = N. 73° E. Table II.
   By calculation N. 73°·2 E

As the H.A. exceeds 6 hours we subtract it from 12 hours and enter the Table with the remainder, or 5h. 20m.

N.B.—The sum or difference found as above is also the correction in longitude for 1′ error in the latitude, so that two important elements are found simultaneously.

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* The numbers for intermediate degrees and hour-angles are easily taken out at sight and with sufficient accuracy for all purposes for which these Tables are intended—*vide* page 19.

FOR HOUR-ANGLES LESS THAN AN HOUR.

When the Hour-angle is less than one hour, find the azimuth for one hour and multiply it by the minutes expressed as the decimal of an hour.

Example.

Lat. 32° N., Dec. 12° N., H.A. 0h. 36m. E. of Mer.

For the above we have 2′·33 S.
And ·79 N.

Diff. 1·54 S. = S. 37° E. Table II.

∴ The Bearing at 0h. 36m. = 37° × ·6 = 22° or S. 22° E.

This is true, nearly, because, near the meridian, the azimuth varies as the Hour-angle, approximately.

NOTES.

I. In actual practice it will generally be sufficient to take from Table II. the Bearing which most nearly agrees with the sum or difference; or the Mean Bearing, as the case may be.

II. If we wish to find it more exactly, we take the diff. of the *sum or diff.* and the *first* of the two numbers between which it lies, also the diff. of these latter, and make a fraction with the two differences. This fraction multiplied by 2° or 120′, gives the number of minutes to be added to the first of the two bearings. *Vide* Examples (*c*) and (*d*) page 19.

III. The H.A. for the Lat. is on the left-hand side of Table I., that for the Dec. on the *right.* It will be noticed that the intervals in the latter are greater than those in the former; but as the numbers corresponding to them change very slowly it will suffice to take the nearest H.A. to that given, or the mean of the two between which it lies.

Thus for 3h. 4m. we should take 3h. 6m.; but for 3h. 16m. we should take the mean between 3h. 6m. and 3h. 26m. and so on.

The H.A.'s for the latitude may be taken out to the nearest 4m. by taking the means; and the latitude and declination to the nearest degree in like manner.

The easiest way to take the means is to add half the difference of the two numbers to the lesser number, which can readily be done at sight.

When the H.A. lies between two of those given and the latitude or declination consists of an odd number of degrees, proceed as in the following

Examples.

(*a*) Lat. 43° N., H.A. 2h. 4m.

We have Lat. 42°	and 2h. 0m.	=	1·56′
" 44°	" 2h. 8m.	=	1·54′
Means:—43°	" 2h. 4m.	=	1·55′

(*b*) Dec. 15°, H.A. 2h. 11m.

We have Dec. 14°	and H.A. 2h. 8m.	=	·47′
" 16°	" " 2h. 14m.	=	·52′
Means:—15°	" " 2h. 11m.	=	·49′.

The above are easily taken out at sight.

EXPLANATION OF TABLE II.

The construction of this Table is fully explained on page 57.

When the latitude and bearing are given to find the correction it is taken out at sight.

Thus for Lat. 50°	and Bearing 60°	we have	·90
" 50°	" " 61°	" "	·86
" 51°	" " 61°	" "	·88

In the latter we take the mean of 50° & 60°, 52° & 62°, the two even degrees next less and the two even degrees next greater than those given.

Conversely: For Lat. 50°	and corr. 90′	the bearing is	60°
" 50°	" 86′	" "	61°
" 51°	" 88′	" "	61°

The bearings found in this manner will generally be within a few minutes of those obtained by calculation, and sufficiently accurate for laying off position lines or finding the compass correction, &c.

When still greater accuracy is desired proceed as follows:

(*c*) To find the bearing for lat. 40° and 1′·15—

$$\begin{array}{rl} & {}' \quad \text{Diff.} \\ \text{We have } & \left.\begin{array}{r}1{\cdot}15\\1{\cdot}17\end{array}\right\} 2 \\ & \left.\begin{array}{r}1{\cdot}17\\1{\cdot}09\end{array}\right\} 8 \end{array} \quad \therefore \frac{2}{8} \times 2^\circ = \frac{4}{8} = \frac{1}{2} = 30'$$

which, being added to the lesser bearing we have 48° 30′, *vide* below

(*d*) To find the bearing for lat. 41° and 1′·31—

$$\begin{array}{rl} & {}' \quad \text{Diff.} \\ \text{We have } & \left.\begin{array}{r}1{\cdot}31\\1{\cdot}35\end{array}\right\} 4 \\ & \left.\begin{array}{r}1{\cdot}35\\1{\cdot}30\end{array}\right\} 5 \end{array} \quad \therefore \frac{4}{5} \times 2^\circ = \frac{8}{5} = 1\frac{3}{5} = 1^\circ\, 36'$$

which, being added to the lesser bearing we have 45° 36′

In Ex. (*c*) 1·17 and 1·09 are the numbers in Lat. 40° column

between which 1·15 lies; and in (*d*) the Lat. being 41° the numbers are taken from the columns for Lat. 40° and 42°.

The *name* of the correction for longitude is found as directed on p. 8, or by reversing one of the letters of the Bearing: thus if the body bore S.E. we should have N.E., or S.W. denoting that corrections N. and E. go together, as also S. and W.

TABLE II. is used also for finding

THE ERROR IN LONGITUDE

DUE TO 1′ ERROR IN ALTITUDE WHEN THE BEARING IS KNOWN.

For this purpose we take the nearest or mean Bearing from the last column but one of the table, then with the latitude and this Bearing take out the correction as before. Thus: for Lat. 40° and Bearing 46°, the correction is 1′·80; and for Lat. 34° and Bearing 69° it is 1′·29, the mean between 1′·34 and 1′·25 the numbers which correspond to 65° and 74°, between which Bearings 69° lies, and so on. From lat. 0° to 34° the correction is taken from the first page of Table II.

TO NAME THE CORRECTION.

When the observed altitude is too *small* the correction takes the same name as the Bearing.

Thus, if the body bore S.E., the correction would be East; or if S.W., it would be West. When too large it takes the opposite name.

Or, we could multiply the above correction by 4 to convert it into seconds, and apply it to the Hour-angle, subtracting if the observed altitude is too small and adding if too great.

The Table also shows the degree of dependence in an observation, as far as the altitude is concerned. Thus in the above example it is seen that each minute of error in the altitude produces an error of 1′·80 in the longitude or of 7·20 sec. in the Hour-angle.

TABLE III.

THE EX-MERIDIAN TABLE.

With the latitude and altitude take out N.; then with N. and the H.A. find the Reduction.

Example: Lat. 50°, Alt. 40°, H.A. $0^h\,15^m$
(1) Lat. 50° and Alt. 40° give ·85 for N.
(2) N. ·85 and H.A. 0·15 give 6·2 or 6′·12″.

This added to the true altitude gives the Mer. Alt.

The Latitude is then found by the Mer. Alt. Rule.

When the declination is small its effect upon the Reduction may be neglected; but when considerable a second correction, *always subtractive*, may be taken from the small table annexed.

Example II. Lat. 50° N., Alt. 60°, Dec. 20° N., H.A. 18m. 30s.
(1) For lat. 50° and alt. 60° N. we have 1·29
(2) For N. 1·29 (or 1·30) and 18m. 30s. Red. = 14′·5
(3) For Dec. 20° and Red. 14·5 (or 15) Corr. = ·9—

∴ The true Reduction = 13·6 or 13′ 36″

which, added* to the true alt., gives the Mer. Alt. For 18m. 30s. we take the mean of the numbers for 18m. and 19m.; or multiply the difference of the numbers for 18m. and 19m. by ·5 and add to the lesser. In this way we can take out the Reduction for any number of seconds in the H.A., for we have only to multiply the diff. by the number of seconds, expressed as the decimal of a minute, and add the result to the lesser number as before.

The values of the Reduction are tabulated to 35m. which will probably be found sufficient for most purposes. Should, however, the H.A. be greater than this, take out the Reduction for its half and multiply it by 4.

Thus, for 40m. 24s., whose half is 20m. 12s., or 20·2m. and N. 1·30,

We have N. 1·30 and 20m.	= 17
Diff. 1·8 × ·2	= 0·4
	17·4
	4
∴ Reduction for 40m. 24s.	= 69·6

If in the above the dec. were 20°, we should have as before—

	69·6
Dec. 20° and 70′	= 4·2
∴ The true Reduction	= 65·4

Among other advantages, the above little table shows at a glance the value of the reduction for any number of minutes within the limits tabulated, and the effect that an error of a given number of minutes in the H.A. would produce on the resulting latitude, and therefore the degree of dependence.

* In observations near the Meridian *below* the pole, the Reduction is to be subtracted, instead of added.

EXTENSION OF TABLES I.—III. TO LAT. 80° N. or S.

Tab. I.—When the latitude exceeds 58°, take the equivalent latitude from Tab. (i.), and proceed as follows :—

Example I.

Lat. 70° N., Dec. 20° N., H.A. 2h. 8m.

Tab. (i.)	Tab. (I.)	
Lat. 70° = 54°	Lat. 54° and H.A. 2h. 8m. = 2′·20 × 2	= 4·40
Multr. = 2	Dec. 20° and H.A. 2h. 8m.	= ·68
	Diff.	= 3·72

∴ Long. Corr. = 3·72.

Tab. II.—When the latitude exceeds 60°, take the equivalent latitude from Tab. (ii.), and with this latitude and the bearing take out the Long. Corr. as before, and multiply it by the number under the latitude.

Example II.

Lat. 74°, Bearing 60°.

Tab. (ii.)	Tab. (II.)
Lat. 74° = 56°	Lat. 56° and Bearing 60° = 1·03
Multr. = 2	

∴ Long. Corr. = 1·03 × 2 = 2·06.

Conversely : Given Lat. 74° and Long. Corr. 2·06, to find the Bearing.
We have 2·06 ÷ 2 = 1·03, and Lat. 74° = Lat. 56°.
∴ Lat. 56° and 1·03 = Bearing 60°.

EXTENSION OF EX-MER. TABLES TO LAT. OR ALT. 80°.

When the latitude is greater than 60°, take the equivalent latitude from Tab. (iii.), and find N. for this latitude, and the given altitude. With N. and the H.A. find the reduction as before, and divide by the number standing under the latitude in Tab. (iii.)

Example I.

Lat. 74° N., Alt. 12°, Dec. 4° S., H.A. 16m. 6s.

Tab. (iii.)	Tab. (III.)
Lat. 74° = 56°	Lat. 56°, Alt. 12° = ·57 (N.)
Divisor = 2	

N. ·57 and 16m. 4s. = 4′·8

∴ The reduction $= \frac{4'\cdot 8}{2} = 2'\cdot 4 = 2'24''$.

When the altitude exceeds 60°, take the equivalent altitude from Tab. (iii.) and with this and the latitude take out N. Find the Reduction as before and multiply it by the number standing under the Alt. in Tab. (iii.)

Example II.

Alt. 72°, Lat. 10° N., H.A. 10m.

Tab. (iii.)	Tab. (III.)
Alt. 72° = 52°	Lat. 10°, Alt. 52° = 1·59 (N.)
Multr. 2	

N. 1·59 and H.A. 10m. = 5′·3

∴ The Reduction = 5′·3 × 2 = 10′·6 or 10′ 36″.

THE TRUE ALTITUDE NEAR THE MERIDIAN AND THE MERIDIAN ALTITUDE BEING KNOWN, TO FIND THE H.A., NEARLY.

Example I.

Lat. 50° N., Alt. near Mer. 39° 53′ 48″, Mer. Alt. 40° 0′ 0″: to find H.A., approximately.

$$\left.\begin{array}{l}\text{Lat. } 50^\circ\\ \text{Alt. } 40^\circ\end{array}\right\} = \cdot 85\ (\text{N.}) \qquad \begin{array}{lr}\text{Mer. Alt.} & 40^\circ\ 0'\ 0''\\ \text{Alt. nr. Mer.} & \underline{39\ 53\ 48}\\ \text{Diff.}\ \ \ldots & =\ 6\ 12\ \ (=6'\cdot 2)\end{array}$$

∴ N. ·85 and 6′·2 = 15m. 0s., the H.A. required.

Example II.

Lat. 50° N., Alt. 60°, Dec. 20° N., Mer. Alt. 60° 0′ 0″
Alt. near Mer. 59 46 24

$$\begin{array}{lll} & & 13\ 36 = 13'\cdot 6\\ \left.\begin{array}{l}\text{Lat. } 50^\circ\\ \text{Alt. } 60^\circ\end{array}\right\} = 1\cdot 29\ \text{N.} & \text{Dec. } 20^\circ\ \&\ 15' & = \underline{+\cdot 9}\\ & & 14\cdot 5\end{array}$$

N. 1·29 and 14′5 = 18m. 28s.

To obtain this, we see that, in the line for N. 1·30, 14·5 lies between 13·8 and 15·3 the numbers for 18m. and 19m.

$$\begin{array}{rl} & \text{Diff.}\\ \therefore\ \text{We have given nr. } 14\cdot 5 & \cdot 7\\ 18\text{m.} = 13\cdot 8 & \\ 19\text{m.} = 15\cdot 3 & 1\cdot 5\end{array} \qquad \therefore\ \frac{7}{15} \times 60'' = 28\ \text{sec.}$$

∴ The H.A. required is 18m. 28 sec.

Both observations must be accurately taken and the first corrected for the run in the interval.

This method may be employed when the Sun has been obscured till it is too late to take the usual observations for time.

When the Ship time is not known with any degree of certainty a second ex-meridian should if possible be taken in the afternoon at about the same altitude as the first, and the mean of the two latitudes (reduced to noon) may be taken as the true latitude. By this means any errors in the reductions due to errors in the time are eliminated.

COMBINED EX-MERIDIANS.

When a second observation is taken on the same side of the meridian, and the second latitude confirms the first, it may be assumed to be the true latitude.

But, if not, take the difference of the two latitudes, multiply it by the lesser H.A., divide by the elapsed time,* and apply the result

* Or multiply the Diff. Lat. by the Nr. taken from Tab. (iv.), p. 35.

to the latitude given by the observation nearest to the meridian, adding or subtracting according as this latitude is greater or less than the other.

When the observations are on opposite sides of the meridian also apply the Correction to the lat. given by the observation nearest to the meridian, but the opposite way, *i.e.*, subtracting or adding according as this latitude is greater or less than the other.

Both observations should be accurately taken and the second corrected for the run in the interval.

Example.

Lat. DR. 50° 0′ N. 1st. Obs., H.A. 23m. 30s. Alt. 39° 39′. 2nd. Obs. H.A. 8m. 20s. Alt. 39° 56′.

	H.A's.
	23 30
	8 20
Interval	15 10

1st Alt.	39° 39′		2nd Alt.	39° 56′
Red	+ 15		Red.	+ 2
	39 54			39 58
Z.D.	50 6	Correction	Z.D.	50 2
Dec.	0 4 S.	$\frac{4 \times 8{\cdot}3}{15{\cdot}2} = 2$	Dec.	0 4 S.
Lat. (1)	50 2 N.		Lat. (2)	49 58 N.
(or by Tab. iv.) corr. = 4′ × ·53 = 2′ to the nearest minute)			Corr.	— 2
			Lat. in	49 56 N.

The Diff. Lat., 4′, multiplied by the lesser H.A. and divided by the interval gives 2′ (about) which is subtracted from Lat. (2) because this Lat. is less than the other. The latitude thus found is for the time of the second observation.

Example for Practice :

The Azimuth.

Lat. 40° N	Dec. 10° N.	H.A. 3·16 E.	Ans. Az. S. 69° E.
,, 30° S.	,, 12° S.	,, 4·20 W.	,, ,, N. 88° W.
,, 22° N.	,, 20° S.	,, 3·48 E.	,, ,, S. 57° E.
,, 32° S.	,, 14° N.	,, 4·12 W.	,, ,, N. 63° W.
,, 50° N.	,, 20° N.	,, 7·16 E.	,, ,, N. 63° E.
,, 58° S.	,, 24° S.	,, 6·52 W.	,, ,, S. 66° W.
,, 44° N.	,, 56° N.	,, 5·30 E.	,, ,, N. 45° E.

The Reduction to the Meridian.

Lat. 50°	Alt 40°	Dec. 0°	H.A. 10m. 5s.	Ans. Red. + 2′ 48″
,, 40°	,, 38°	,, 12° S.	,, 14m. 30s.	,, ,, + 6′ 36″
,, 20°	,, 60°	,, 10° S.	,, 16m. 24s.	,, ,, +16′ 36″
,, 60°	,, 50°	,, 20° N.	,, 17m. 48s.	,, ,, + 7′ 24″
,, 70°	,, 42°	,, 22° N.	,, 12m. 3s.	,, ,, + 1′ 54″
,, 50°	,, 52°	,, 12° N.	,, 32m. 12s.	,, ,, +34′ 24″

LONGITUDE CORRECTION,

TIME-AZIMUTH,

AND

EX-MERIDIAN

TABLES

TABLE I.

For the Longitude Correction,

LATITUDE																	
HA. for Lat.	*a*	0°	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	* HA. for Dec.
	0·00	0·00	0·03	0·07	0·10	0·14	0·18	0·21	0·25	0·29	0·33	0·36	0·40	0·45	0·49	0·53	
H.M.																	H.M.
1.0	3·73	0·00	0·13	0·26	0·39	0·52	0·66	0·79	0·93	1·07	1·21	1·36	1·51	1·66	1·83	1·98	**1.0**
4	3·49	0·00	0·12	0·24	0·37	0·49	0·61	0·74	0·87	1·00	1·13	1·27	1·41	1·55	1·70	1·85	8
8	3·27	0·00	0·11	0·23	0·34	0·46	0·58	0·69	0·82	0·94	1·06	1·19	1·32	1·46	1·59	1·74	12
12	3·08	0·00	0·11	0·22	0·32	0·43	0·54	0·65	0·77	0·88	1·00	1·12	1·24	1·37	1·50	1·64	16
16	2·90	0·00	0·10	0·20	0·30	0·41	0·51	0·62	0·72	0·83	0·94	1·06	1·17	1·29	1·42	1·54	20
20	2·75	0·00	0·09	0·19	0·28	0·39	0·48	0·58	0·68	0·79	0·89	1·00	1·11	1·22	1·31	1·46	24
24	2·60	0·00	0·09	0·18	0·27	0·37	0·46	0·55	0·65	0·75	0·85	0·95	1·08	1·16	1·27	1·38	30
28	2.47	0·00	0·08	0·17	0·26	0·35	0·44	0·53	0·62	0·71	0·80	0·90	1·00	1·10	1·21	1·32	36
32	2·36	0·00	0·08	0·16	0·25	0·33	0·41	0·50	0·59	0·68	0·76	0·85	0·95	1·05	1·15	1·25	40
36	2·25	0·00	0·08	0·16	0·24	0·32	0·40	0·48	0·56	0·64	0·73	0·81	0.91	1·00	1·09	1·19	46
40	2·14	0·00	0·07	0·15	0·22	0·30	0·38	0·46	0·53	0·61	0·70	0·78	0·87	0·95	1·05	1·14	52
44	2·05	0·00	0·07	0·14	0·21	0·29	0·36	0·44	0·51	0·59	0·67	0·75	0·83	0·91	1·00	1·09	56
48	1.96	0·00	0·07	0·14	0·21	0·28	0·35	0·42	0·49	0·56	0·64	0·71	0·79	0·87	0·96	1·04	**2.2**
52	1·88	0·00	0·06	0·13	0·20	0·26	0·33	0·40	0·47	0·54	0·61	0·68	0·76	0·84	0·92	1·00	8
56	1·80	0·00	0·06	0·13	0·19	0·25	0·32	0·38	0·45	0·52	0·59	0·66	0·73	0·80	0·88	0·96	14
2.0	1·73	0·00	0·06	0·12	0·18	0·24	0·30	0·37	0·43	0·50	0·56	0·63	0·70	0·77	0·84	0·92	20
8	1·60	0·00	0·06	0·11	0·17	0·22	0·28	0·35	0·40	0·46	0·52	0·58	0·65	0·71	0·78	0·85	34
16	1·48	0·00	0·05	0·10	0·16	0·21	0·26	0·31	0·37	0·42	0·48	0·54	0·60	0·66	0·72	0·79	48
24	1·38	0·00	0·05	0·10	0·14	0·19	0·24	0·29	0·34	0·39	0·45	0·50	0·56	0.61	0·67	0·73	**3.6**
32	1·28	0·00	0·04	0·09	0·13	0·18	0·23	0·27	0·32	0·37	0·42	0·47	0·52	0·57	0·62	0·68	26
40	1·19	0·00	0·04	0·08	0·12	0·17	0·21	0·25	0·30	0·34	0·39	0·43	0·48	0·53	0·58	0·63	48
48	1·11	0·00	0.04	0·08	0·12	0·16	0·20	0·24	0·28	0·32	0·36	0·40	0·45	0·49	0·54	0·59	**4.16**
56	1·03	0·00	0·04	0·07	0·11	0·15	0·19	0·22	0·26	0·30	0·34	0·38	0·42	0·46	0·50	0·55	**5.4**
3.0	1·00	0·00	0·04	0·07	0·10	0·14	0·18	0·21	0·25	0·29	0·32	0·36	0·40	0·44	0·49	0·53	**6.0**
8	0·93	0·00	0·03	0·06	0·10	0·13	0·16	0·19	0·23	0·27	0·30	0.34	0·38	0·41	0·45	0·50	
16	0·87	0·00	0·03	0·06	0·09	0·12	0·15	0·18	0·22	0·25	0·28	0·32	0·35	0·39	0·42	0·46	
24	0·81	0·00	0·03	0·06	0·08	0·11	0·14	0·17	0·20	0·23	0·26	0·29	0·33	0·36	0·39	0·43	
32	0·75	0·00	0·03	0·05	0·08	0·11	0·13	0·16	0·19	0·22	0·24	0·27	0·30	0·34	0·37	0·40	
40	0·70	0·00	0·02	0·05	0·07	0·10	0·12	0·15	0·17	0·20	0·23	0·25	0·28	0·31	0·34	0·37	
48	0·65	0·00	0·02	0·04	0·07	0·09	0·11	0·14	0·16	0·19	0·21	0·24	0·26	0·29	0·32	0·34	
56	0·60	0·00	0·02	0·04	0·06	0·08	0·10	0·13	0·15	0·17	0·19	0·22	0·24	0·27	0·29	0·32	* Hour-Angle for Declination
4.0	0·58	0·00	0·02	0·04	0·06	0·08	0·10	0·12	0·14	0·17	0·19	0·21	0·23	0·26	0·28	0·31	
8	0·53	0·00	0·02	0·04	0·06	0·07	0·09	0·11	0·13	0·15	0·17	0·19	0·21	0·24	0·26	0·28	
16	0·49	0·00	0·02	0·03	0·05	0·07	0·09	0·10	0·12	0·14	0·16	0·18	0·20	0·22	0·24	0·26	
24	0·44	0·00	0·02	0·03	0·05	0·06	0·08	0·09	0·11	0·13	0·14	0·16	0·18	0·20	0·22	0·24	
32	0·40	0·00	0·01	0·03	0·04	0·06	0·07	0·09	0·10	0·12	0·13	0·15	0·16	0·18	0·20	0·21	
40	0·36	0·00	0·01	0·03	0·04	0·05	0·06	0·08	0·09	0·10	0·12	0·13	0·15	0·16	0·18	0·19	
48	0·32	0·00	0·01	0·02	0·03	0·05	0·06	0·07	0·08	0·09	0·11	0·12	0·13	0·14	0·16	0·17	
56	0·29	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09	0·10	0·12	0·13	0·14	0·15	
5.0	0·27	0·00	0·01	0·01	0·03	0·04	0·05	0·06	0·07	0·08	0·09	0·10	0·11	0·12	0·13	0·14	
8	0·23	0·00	0·01	0.01	0·02	0·03	0·04	0·05	0·06	0·07	0·07	0·08	0·09	0·10	0·11	0·12	
16	0·19	0·00	0·01	0·01	0·02	0·03	0·03	0·04	0·05	0·06	0·06	0·07	0·08	0·09	0·09	0·10	
24	0·16	0·00	0·01	0·01	0·02	0·03	0·03	0·03	0·04	0·04	0·05	0·06	0·06	0·07	0·08	0·08	
32	0·12	0·00	0·01	0·01	0·01	0·02	0·02	0·03	0·03	0·03	0·04	0·04	0·05	0·05	0·06	0·06	
40	0·09	0·00	0.01	0·01	0·01	0·01	0·02	0·02	0·02	0·02	0·03	0·03	0·03	0·04	0·04	0·05	
50	0·04	0·00	0·00	0·00	0·00	0·00	0·01	0·01	0·01	0·01	0·01	0·02	0·02	0·02	0·02	0·02	
6.0	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	
		0°	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	
* DECLINATION																	

For hour-angles less than an hour, *vide* page 18.

TABLE I.

AND THENCE THE TIME-AZIMUTH BY TABLE II.

LATITUDE																	
HA. for Lat.	a	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	* H.A. for Dec.
	0·00	0·58	0·63	0·67	0·73	0·78	0·84	0·90	0·97	1·04	1·11	1·19	1·28	1·35	1·48	1·60	
H.M.																	H.M.
1.0	3·73	2·15	2·33	2·52	2·71	2·92	3·13	3·36	3·60	3·86	4·14	4·45	4·78	5·14	5·53	5·97	**1.0**
4	3·49	2·01	2·18	2·35	2·53	2·71	2·93	3·14	3·37	3·61	3·87	4·15	4·46	4·80	5·17	5·58	8
8	3·27	1·89	2·04	2·21	2·38	2·55	2·74	2·94	3·16	3·39	3·63	3·90	4·19	4·50	4·85	5·23	12
12	3·08	1·78	1·92	2·08	2·24	2·40	2·58	2·77	2·97	3·19	3·42	3·67	3·94	4·24	4·56	4·92	16
16	2·90	1·68	1·81	1·96	2·11	2·27	2·44	2·61	2·80	3·01	3·22	3·46	3·72	4·00	4·31	4·65	20
20	2·75	1·59	1·72	1·85	2·00	2·15	2·30	2·47	2·65	2·84	3·05	3·27	3·52	3·78	4·07	4·40	24
24	2·60	1·50	1·63	1·76	1·89	2·04	2·19	2·35	2·52	2·70	2·89	3·10	3·33	3·59	3·86	4·17	30
28	2·47	1·43	1·55	1·67	1·80	1·93	2·08	2·23	2·39	2·55	2·75	2·95	3·17	3·41	3·67	3·96	36
32	2·36	1·36	1·47	1·59	1·71	1·84	1·98	2·12	2·27	2·44	2·62	2·81	3·01	3·24	3·49	3·77	40
36	2·25	1·30	1·40	1·51	1·63	1·75	1·88	2·02	2·17	2·33	2·49	2·68	2·87	3·09	3·33	3·59	46
40	2·14	1·24	1·34	1·45	1·56	1·67	1·80	1·93	2·07	2·22	2·38	2·56	2·74	2·95	3·18	3·43	52
44	2·05	1·18	1·28	1·38	1·49	1·60	1·72	1·88	1·98	2·12	2·28	2·44	2·62	2·82	3·04	3·28	56
48	1·96	1·13	1·22	1·32	1·43	1·53	1·65	1·77	1·89	2·03	2·18	2·34	2·51	2·70	2·91	3·14	**2.2**
52	1·88	1·09	1·17	1·27	1·37	1·47	1·58	1·69	1·82	1·95	2·09	2·24	2·41	2·59	2·79	3·01	8
56	1·80	1·04	1·13	1·22	1·31	1·41	1·51	1·62	1·74	1·87	2·00	2·15	2·31	2·48	2·67	2·89	14
2.0	1·73	1·00	1·08	1·17	1·26	1·35	1·45	1·56	1·67	1·79	1·92	2·06	2·22	2·38	2·57	2·77	20
8	1·60	0·92	1·00	1·08	1·16	1·25	1·34	1·44	1·54	1·66	1·78	1·91	2·05	2·20	2·37	2·56	34
16	1·48	0·86	0·93	1·00	1·08	1·16	1·24	1·33	1·43	1·53	1·65	1·77	1·90	2·04	2·20	2·37	48
24	1·38	0·79	0·86	0·93	1·00	1·07	1·15	1·24	1·33	1·42	1·53	1·64	1·76	1·84	2·04	2·20	**3.6**
32	1·28	0·74	0·80	0·86	0·93	1·00	1·07	1·15	1·24	1·32	1·42	1·52	1·64	1·78	1·90	2·05	26
40	1·19	0·69	0·74	0·83	0·87	0·93	1·00	1·07	1·15	1·23	1·32	1·42	1·52	1.64	1·77	1·91	48
48	1·11	0·64	0·69	0·75	0·81	0·87	0·93	1·00	1·07	1·15	1·23	1·32	1·42	1·53	1·65	1·78	**4.16**
56	1·03	0·60	0·65	0·70	0·75	0·81	0·87	0·93	1·00	1·07	1·15	1·23	1·32	1·42	1·53	1·66	**5.4**
3.0	1·00	0·58	0·62	0·67	0·73	0·78	0·84	0·90	0·97	1·04	1·11	1·19	1·28	1·38	1·48	1.60	**6.0**
8	0·93	0·54	0·58	0·63	0·68	0·73	0·78	0·84	0·91	0·97	1·04	1·11	1·19	1·28	1·38	1·49	
16	0·87	0·50	0·54	0·59	0·63	0·68	0·73	0·78	0·84	0.90	0·96	1·04	1·11	1·20	1·29	1·38	
24	0·81	0·47	0·51	0·55	0·59	0·63	0·68	0·73	0·78	0·84	0·90	0·96	1·04	1·11	1·20	1·30	
32	0·75	0·43	0·47	0·51	0·55	0·59	0·63	0·68	0·73	0·78	0·84	0·90	0·96	1·04	1·12	1·21	
40	0·70	0·40	0·44	0·47	0·51	0·55	0·59	0·63	0·68	0·72	0·78	0·83	0·90	0·96	1·04	1·12	
48	0·65	0·37	0·41	0·44	0·47	0·51	0·54	0·58	0·63	0·67	0·72	0·77	0·83	0·89	0·96	1·04	
56	0·60	0·35	0·37	0·40	0·44	0·47	0·50	0·54	0·58	0·62	0·67	0·71	0·77	0·83	0·89	0·96	
4.0	0·58	0·33	0·36	0·39	0·42	0·45	0·48	0·52	0·56	0·60	0·64	0·69	0·74	0·79	0·86	0·92	
8	0·53	0·31	0·33	0·36	0·39	0·41	0·45	0·48	0·51	0.55	0·59	0·63	0·68	0·73	0·79	0·85	
16	0·49	0·28	0·30	0·33	0·35	0·38	0·41	0·44	0·47	0·50	0·54	0·58	0·62	0·67	0·72	0·78	
24	0·44	0·26	0·28	0·30	0·32	0·35	0·37	0·40	0·43	0·46	0·49	0·53	0·57	0·61	0·66	0·71	
32	0·40	0·23	0·25	0·27	0·29	0·32	0·34	0·36	0·39	0·42	0·45	0·48	0·52	0·56	0·60	0·65	
40	0·36	0·21	0·23	0·25	0·26	0·28	0·30	0·33	0·35	0·38	0·40	0·43	0·47	0·50	0·54	0·58	
48	0·32	0·19	0·20	0·22	0·24	0·25	0·27	0·29	0·31	0·34	0·36	0·39	0·42	0·45	0·48	0·52	
56	0·29	0·17	0·18	0·19	0·21	0·22	0·24	0·26	0·28	0·30	0·32	0·34	0·37	0·39	0·42	0·46	
5.0	0·27	0·15	0·17	0·18	0·19	0·21	0·22	0·24	0·26	0·28	0·30	0·32	0·34	0·37	0·40	0·43	
8	0·23	0·13	0·14	0·16	0·17	0·18	0·19	0·21	0·22	0·24	0·26	0·27	0·29	0·32	0·34	0·37	
16	0·19	0·11	0·12	0·13	0·14	0·15	0·16	0·17	0·19	0·20	0·22	0·23	0·25	0·27	0·29	0·31	
24	0·16	0·09	0·10	0·11	0·11	0·12	0·13	0·14	0·15	0·16	0·18	0·19	0·20	0·22	0·23	0·25	
32	0·12	0·07	0·08	0·08	0·09	0·10	0·10	0·11	0·12	0·13	0·14	0·15	0·16	0·17	0·19	0·20	
40	0·09	0·05	0·05	0·06	0·06	0·07	0·07	0·08	0·08	0·09	0·10	0·10	0·11	0·12	0·13	0·14	
50	0·04	0·02	0·03	0·03	0·03	0·04	0·04	0·04	0·04	0·04	0·05	0·05	0·06	0.06	0·06	0·07	
6.0	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	
	a	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	
DECLINATION																	

* Hour-Angle for Declination.

For hour-angles less than an hour, *vide* page 18.

TABLE II.

For Single and Double Chronometer Corrections,

LATITUDE.

Bearing.	0°	4°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	32°	34°	Dep.
	a	1·00	1·01	1·02	1·02	1·03	1·04	1·05	1·06	1·08	1·09	1·11	1·13	1·15	1·18	1·21	*a'*
10°	5·67′	5·70′	5·73′	5·76′	5·79′	5·85′	5·91′	5·97′	6·03′	6·12′	6·21′	6·30′	6·42′	6·55′	6·69	6·84′	5·76′
12	4·71	4·72	4·75	4·78	4·81	4·85	4·89	4·95	5·01	5·08	5·16	5·28	5·34	5·43	5·55	5·67	4·70
14	4·01	4·02	4·04	4·06	4·09	4·12	4·16	4·20	4·26	4·32	4·38	4·46	4·54	4·63	4·73	4·84	4·13
16	3·49	3·50	3·52	3·54	3·56	3·59	3·62	3·66	3·70	3·76	3·82	3·88	3·94	4·02	4·11	4·21	3·63
18	3·08	3·09	3·11	3·13	3·15	3·18	3·20	3·24	3·28	3·32	3·37	3·43	3·49	3·55	3·63	3·71	3·24
20	2·75	2·76	2·78	2·79	2·81	2·83	2·86	2·89	2·92	2·96	3·01	3·06	3·12	3·17	3·24	3·31	2.92
22	2·47	2·47	2·48	2·50	2·52	2·54	2·57	2·60	2·63	2·66	2·70	2·75	2·80	2·86	2·92	2·98	2·67
24	2·25	2·26	2·27	2·28	2·30	2·32	2·34	2·37	2·39	2·43	2·46	2·50	2·55	2·59	2·65	2·71	2·46
26	2·05	2·05	2·07	2·08	2·10	2·11	2·13	2·15	2·18	2·21	2·24	2·28	2·32	2·37	2·42	2·47	2·28
28	1·88	1·88	1·90	1·91	1·92	1·94	1·96	1·98	2·00	2·03	2·06	2·09	2·13	2·17	2·22	2·27	2·13
30	1·73	1·73	1·75	1·76	1·77	1·78	1·80	1·82	1·84	1·87	1·89	1·92	1·96	2·00	2·04	2·09	2·00
32	1·60	1·60	1·62	1·63	1·64	1·65	1·66	1·68	1·70	1·73	1·75	1·78	1·81	1·85	1·89	1·93	1·89
34	1·48	1·48	1·49	1·50	1·51	1·53	1·54	1·56	1·57	1·60	1·62	1·65	1·68	1·71	1·75	1·79	1·79
36	1·38	1·38	1·39	1·40	1·41	1·42	1·44	1·45	1·47	1·49	1·51	1·53	1·55	1·59	1·62	1·66	1·70
38	1·28	1·28	1·28	1·29	1·30	1·31	1·32	1·34	1·35	1·37	1·39	1·41	1·44	1·48	1·51	1·54	1·62
40	1·19	1·19	1·20	1·21	1·22	1·23	1·24	1·25	1·27	1·28	1·30	1·32	1·35	1·38	1·41	1·44	1·56
42	1·11	1·11	1·12	1·13	1·14	1·14	1·15	1·17	1·18	1·20	1·22	1·24	1·26	1·28	1·31	1·34	1·49
44	1·04	1·04	1·04	1·05	1·06	1·07	1·08	1·09	1·10	1·12	1·13	1·15	1·17	1·20	1·22	1·25	1·44
46	0·97	0·97	0·98	0·98	0·99	1·00	1·01	1·02	1·03	1·04	1·06	1·07	1·09	1·11	1·14	1·16	1·39
48	0·90	0·90	0·91	0·91	0·92	0·93	0·94	0·95	0·96	0·97	0·99	1·00	1·02	1·04	1·06	1·09	1·35
50	0·84	0·84	0·85	0·85	0·86	0·87	0·87	0·88	0·89	0·91	0·92	0·93	0·95	0·97	0·99	1·01	1·31
52	0·78	0·78	0·79	0·79	0·80	0·80	0·81	0·82	0·83	0·84	0·85	0·87	0·88	0·90	0·92	0·94	1·27
54	0·73	0·73	0·73	0·74	0·74	0·75	0·75	0·76	0·77	0·78	0·79	0·81	0·82	0·84	0·86	0·88	1·24
56	0·67	0·67	0·68	0·68	0·69	0·69	0·70	0·71	0·71	0·72	0·73	0·75	0·77	0·78	0·79	0·81	1·21
58	0·63	0·63	0·63	0·63	0·64	0·64	0·65	0·66	0·66	0·67	0·68	0·69	0·71	0·72	0·74	0·75	1·18
60	0·58	0·58	0·59	0·59	0·59	0·60	0·60	0·61	0·62	0·62	0·63	0·65	0·66	0·67	0·68	0·70	1·15
62	0·53	0·53	0·54	0·54	0·54	0·55	0·55	0·56	0·56	0·57	0·58	0·59	0·60	0·61	0·63	0·64	1·13
64	0·49	0·49	0·50	0·50	0·50	0·51	0·51	0·52	0·52	0·53	0·54	0·55	0·56	0·56	0·57	0·59	1·11
66	0·45	0·45	0·45	0·45	0·46	0·46	0·46	0·47	0·47	0·48	0·49	0·50	0·50	0·51	0·52	0·54	1·09
68	0·40	0·40	0·40	0·41	0·41	0·41	0·42	0·42	0·43	0·43	0·44	0·45	0·45	0·47	0·47	0·49	1·08
70	0·36	0·36	0·36	0·37	0·37	0·37	0·37	0·38	0·38	0·39	0·39	0·40	0·41	0·42	0·43	0·44	1·06
72	0·33	0·33	0·33	0·33	0·34	0·34	0·34	0·34	0·35	0·35	0·36	0·36	0·37	0·37	0·38	0·39	1·05
74	0·29	0·29	0·29	0·29	0·30	0·30	0·30	0·31	0·31	0·31	0·32	0·32	0·33	0·33	0·34	0·34	1·04
76	0·25	0·25	0·25	0·25	0·25	0·26	0·27	0·27	0·27	0·27	0·27	0·28	0·28	0·29	0·29	0·30	1·03
78	0·21	0·21	0·21	0·21	0·21	0·22	0·22	0·22	0·22	0·23	0·23	0·23	0·23	0·24	0·25	0·25	1·02
80	0·18	0·18	0·18	0·18	0·18	0·18	0·18	0·18	0·19	0·19	0·19	0·20	0·20	0·20	0·21	0·21	1·02
82	0·14	0·14	0·14	0·14	0·14	0·14	0·14	0·15	0·15	0·15	0·15	0·15	0·15	0·16	0·17	0·17	1·01
84	0·10	0·10	0·10	0·10	0·10	0·10	0·11	0·11	0·11	0·11	0·11	0·11	0·11	0·12	0·12	0·13	1·01
86	0·07	0·07	0·07	0·07	0·07	0·07	0·07	0·07	0·07	0·08	0·08	0·08	0·08	0·08	0·08	0·08	1·00
88	0·03	0·03	0·03	0·04	0·04	0·04	0·04	0·04	0·04	0·04	0·04	0·04	0·04	0·04	0·04	0·04	1·00
89	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	1·00
90	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	1·00
	0·00	0·07	0·14	0·18	0·21	0·25	0·29	0·33	0·36	0·40	0·45	0·49	0·53	0·58	0·63	0·67	

For Latitudes above 60° *see* Table (ii.), p. 35.

TABLE II.

Time-Azimuth, Alt.-Azimuth, Great-Circle Sailing, &c.

Bearing.	LATITUDE.															Bearing for Alt.-Error	For the Alt.-Azimuth
	0°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	60°		
	a	1·21	1·24	1·27	1·31	1·35	1·39	1·44	1·49	1·56	1·62	1·70	1·79	1·89	2·00	DEG	
°	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	°	′
10	5·67	6·84	7·01	7·20	7·40	7·63	7·88	8·16	8·48	8·82	9·21	9·65	10·14	10·70	11·33	10	·98
12	4·71	5 67	5·81	5·97	6·14	6·33	6·54	6·77	7·03	7·32	7·64	8·00	8·41	8·88	9·41	12	·98
14	4·01	4·84	4·95	5·09	5·23	5·40	5·58	5·77	5·99	6·24	6·51	6·82	7·17	7·57	8·02	14	·97
16	3·49	4·21	4·31	4·43	4·55	4·69	4·85	5·02	5·21	5·42	5·66	5·93	6·24	6·58	6·97	17	·96
18	3·08	3·71	3·80	3·90	4·02	4·14	4·28	4·43	4·60	4·79	5·00	5·24	5·50	5·81	6·15	19	·95
20	2·75	3·31	3·39	3·49	3·59	3·70	3·82	3·95	4·11	4·27	4·46	4·67	4·91	5·19	5·49	21	·94
22	2·47	2·98	3·06	3·14	3·23	3·33	3·44	3·56	3·70	3·85	4·02	4·21	4·43	4·67	4·95	24	·93
24	2·25	2·71	2·77	2·85	2·93	3·02	3·12	3·23	3·36	3·49	3·65	3·82	4·02	4·24	4·49	26	·91
26	2·05	2·47	2·53	2·60	2·68	2·76	2·85	2·95	3·06	3·19	3·33	3·49	3·66	3·87	4·10	29	·90
28	1·88	2·27	2·32	2·39	2·45	2·53	2·61	2·71	2·81	2·92	3·05	3·20	3·36	3·55	3·76	32	·88
30	1·73	2·09	2·14	2·20	2·26	2·33	2·41	2·49	2·60	2·69	2·81	2·95	3·10	3·27	3·46	35	·87
32	1·60	1·93	1·98	2·03	2·09	2·15	2·22	2·30	2·39	2·49	2·60	2·72	2·86	3·02	3·20	39	·85
34	1·48	1·79	1·83	1·88	1·93	1·99	2·06	2·13	2·22	2·31	2·41	2·52	2·65	2·80	2·96	42	·83
36	1·38	1·66	1·70	1·74	1·80	1·85	1·91	1·98	2·06	2·14	2·24	2·34	2·46	2·60	2·75	46	·81
38	1·28	1·54	1·58	1·62	1·67	1·72	1·78	1·84	1·91	1·99	2·08	2·18	2·29	2·41	2·56	51	·79
40	1·19	1·44	1·47	1·51	1·55	1·60	1·66	1·72	1·78	1·85	1·94	2·03	2·13	2·25	2·38	57	·77
42	1·11	1·34	1·37	1.41	1·45	1·49	1·54	1·60	1·66	1·73	1·80	1·89	1·99	2·09	2·22	65	·74
44	1·04	1·25	1·28	1·31	1·35	1·39	1·44	1·49	1·55	1·61	1·68	1·76	1·85	1·95	2·07	74	·72
46	0·97	1·16	1·19	1·23	1·26	1·30	1·34	1·39	1·44	1·50	1·56	1·64	1·73	1·82	1·93	90	·69
48	0·90	1·09	1·11	1·14	1·17	1·21	1·25	1·30	1·35	1·40	1·46	1·53	1·61	1·70	1·80		·67
50	0·84	1·01	1·04	1·06	1·09	1·13	1·16	1·21	1·25	1·31	1·36	1·43	1·50	1·58	1·68		·64
52	0·78	0·94	0·96	0·99	1·01	1·05	1·09	1·12	1·17	1·22	1·27	1·33	1·40	1·47	1·56		·62
54	0·73	0·88	0·90	0·92	0·95	0·98	1·01	1·04	1·09	1·13	1·18	1·23	1·30	1·37	1·45		·59
56	0·67	0·81	0·83	0·85	0·88	0·91	0·94	0·97	1·01	1·05	1·10	1·15	1·21	1·27	1·35		·56
58	0·63	0·75	0·77	0·79	0·81	0·84	0·87	0·90	0·93	0·97	1·01	1·06	1·12	1·18	1·25		·53
60	0·58	0·70	0·71	0·73	0·75	0·78	0·80	0·83	0·86	0·90	0·94	0·98	1·03	1·09	1·15		·50
62	0·53	0·64	0·66	0·67	0·69	0·72	0·74	0·76	0·79	0·83	0·86	0·90	0·95	1·00	1·06		·47
64	0·49	0·59	0·60	0·62	0·64	0·66	0·68	0·70	0·73	0·76	0·79	0·83	0·87	0·92	0·97		·44
66	0·45	0·54	0·55	0·56	0·58	0·60	0·62	0·64	0·66	0·69	0·72	0·76	0·79	0·84	0·89		·41
68	0·40	0·49	0·50	0·51	0·53	0·54	0·56	0·58	0·60	0·63	0·65	0·69	0·72	0·76	0·81		·37
70	0·36	0·44	0·45	0·46	0·47	0·49	0·51	0·52	0·54	0·57	0·59	0·62	0·65	0·68	0·73		·34
72	0·33	0·39	0·40	0·41	0·42	0·44	0·45	0·47	0·49	0·51	0·53	0·55	0·58	0·61	0·65		·31
74	0·29	0·34	0·36	0·36	0·37	0·38	0·40	0·41	0·43	0·44	0·46	0·49	0·52	0·54	0·57		·28
76	0·25	0·30	0·31	0·31	0·32	0·33	0·34	0·36	0·37	0·39	0·40	0·42	0·45	0·47	0·50		·24
78	0·21	0·25	0·26	0·27	0·28	0·29	0·29	0·30	0·32	0·33	0·34	0·36	0·38	0·40	0·42		·21
80	0·18	0·21	0·22	0·22	0·23	0·24	0·24	0·25	0·26	0·27	0·29	0·30	0·31	0·33	0·35		·17
82	0·14	0·17	0·17	0·18	0·18	0·19	0·19	0·20	0·21	0·22	0·23	0·24	0·25	0·26	0·28		·14
84	0 10	0·13	0·13	0·13	0·14	0·14	0·14	0·15	0·16	0·16	0·17	0·18	0·19	0·20	0·21		·10
86	0·07	0·08	0·08	0·09	0·09	0·09	0·10	0·10	0·10	0·11	0·11	0·12	0·12	0·13	0·14		·07
88	0·03	0·04	0·04	0·04	0·04	0·05	0·05	0·05	0·05	0·05	0·06	0·06	0·06	0·07	0·07		·03
89	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·01	0·02	0·02	0·02	0·02	0·02	0·02	0·02		·02
90	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00		·00
	0·00	0·67	0·73	0·78	0·84	0·90	0·97	1·04	1·11	1·19	1·28	1·38	1·48	1·60	1·73		

For Latitudes above 60° *see* Table (ii.), p. 35.

TABLE IIa.

For Single and Double.

Speed, Time & Distance	CORRECTION IN LONGITUDE FOR ERROR IN D.R. LATITUDE.																
	Nr. from Tab.II.	′ 2	′ 3	′ 4	′ 5	′ 6	′ 7	′ 8	′ 9	′ 10	′ 11	′ 12	′ 13	′ 14	′ 15	′ 16	Nr. from Tab.II.
mins.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
3	0·05	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·7	0·7	0·8	0·05
6	0·10	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1.4	1·5	1·6	0·10
9	0·15	0·3	0·4	0·6	0·7	0·9	1·0	1·2	1·3	1·5	1·6	1·8	1·9	2·1	2·2	2·4	0·15
12	0·20	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·6	2·8	3·0	3·2	0·20
15	0·25	0·5	0·7	1·0	1·2	1·5	1·7	2·0	2·2	2·5	2·7	3·0	3·2	3·5	3·7	4·0	0·25
18	0·30	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7	3·0	3·3	3·6	3·9	4·2	4·5	4·8	0·30
21	0·35	0·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1	3·5	3·8	4·2	4·5	4·9	5·2	5·6	0·35
24	0·40	0·8	1·2	1·6	2·0	2·4	2·8	3·2	3·6	4·0	4·4	4·8	5·2	5·6	6·0	6·4	0·40
27	0·45	0·9	1·3	1·8	2·2	2·7	3·1	3·6	4·0	4·5	4·9	5·4	5·8	6·3	6·7	7·2	0·45
30	0·50	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	7·5	8·0	0·50
33	0·55	1·1	1·6	2·2	2·7	3·3	3·8	4·4	4·9	5·5	6·0	6·6	7·1	7·7	8·2	8·8	0·55
36	0·60	1·2	1·8	2·4	3·0	3·6	4·2	4·8	5·4	6·0	6·6	7·2	7·8	8·4	9·0	9·6	0·60
39	0·65	1·3	1·9	2·6	3·2	3·9	4·5	5·2	5·8	6·5	7·1	7·8	8·4	9·1	9·7	10·4	0·65
42	0·70	1·4	2·1	2·8	3·5	4·2	4·9	5·6	6·3	7·0	7·7	8·4	9·1	9·8	10·5	11·2	0·70
45	0·75	1·5	2·2	3·0	3·7	4·5	5·2	6·0	6·7	7·5	8·2	9·0	9·7	10·5	11·2	12·0	0·75
48	0·80	1·6	2·4	3·2	4·0	4·8	5·6	6·4	7·2	8·0	8·8	9·6	10·4	11·2	12·0	12·8	0·80
51	0·85	1·7	2·5	3·4	4·2	5·1	5·9	6·8	7·6	8·5	9·3	10·2	11·0	11·9	12·7	13·6	0·85
54	0·90	1·8	2·7	3·6	4·5	5·4	6·3	7·2	8·1	9·0	9·9	10·8	11·7	12·6	13·5	14·4	0·90
57	0·95	1·9	2·8	3·8	4·7	5·7	6·6	7·6	8·5	9·5	10·4	11·4	12·3	13·3	14·2	15·2	0·95
	1·00	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	10·0	11·0	12·0	13·0	14·0	15·0	16·0	1·00
	1·05	2·1	3·1	4·2	5·2	6·3	7·3	8·4	9·4	10·5	11·5	12·6	13·6	14·7	15·7	16·8	1·05
	1·10	2·2	3·3	4·4	5·5	6·6	7·7	8·8	9·9	11·0	12·1	13·2	14·3	15·4	16·5	17·6	1·10
	1·15	2·3	3·4	4·6	5·7	6·9	8·0	9·2	10·3	11·5	12·6	13·8	14·9	16·1	17·2	18·4	1·15
	1·20	2·4	3·6	4·8	6·0	7·2	8·4	9·6	10·8	12·0	13·2	14·4	15·6	16·8	18·0	19·2	1·20
	1·25	2·5	3·7	5·0	6·2	7·5	8·7	10·0	11·2	12·5	13·7	15·0	16·2	17·5	18·7	20·0	1·25
	1·30	2·6	3·9	5·2	6·5	7·8	9·1	10·4	11·7	13·0	14·3	15·6	16·9	18·2	19·5	20·8	1·30
	1·35	2·7	4·0	5·4	6·7	8·1	9·4	10·8	12·1	13·5	14·8	16·2	17·5	18·9	20·2	21·6	1·35
	1·40	2·8	4·2	5·6	7·0	8·4	9·8	11·2	12·6	14·0	15·4	16·8	18·2	19·6	21·0	22·4	1·40
	1·45	2·9	4·3	5·8	7·2	8·7	10·1	11·6	13·0	14·5	15·9	17·4	18·8	20·3	21·7	23·2	1·45
	1·50	3·0	4·5	6·0	7·5	9·0	10·5	12·0	13·5	15·0	16·5	18·0	19·5	21·0	22·5	24·0	1·50
	1·55	3·1	4·6	6·2	7·7	9·3	10·8	12·4	13·9	15·5	17·0	18·6	20·1	21·7	23·2	24·8	1·55
	1·60	3·2	4·8	6·4	8·0	9·6	11·2	12·8	14·4	16·0	17·6	19·2	20·8	22·4	24·0	25·6	1·60
	1·65	3·3	4·9	6·6	8·2	9·9	11·5	13·2	14·8	16·5	18·1	19·8	21·4	23·1	24·7	26·4	1·65
	1·70	3·4	5·1	6·8	8·5	10·2	11·9	13·6	15·3	17·0	18·7	20·4	22·1	23·8	25·5	27·2	1·70
	1·75	3·5	5·2	7·0	8·7	10·5	12·2	14·0	15·7	17·5	19·2	21·0	22·7	24·5	26·2	28·0	1·75
	1·80	3·6	5·4	7·2	9·0	10·8	12·6	14·4	16·2	18·0	19·8	21·6	23·4	25·2	27·0	28·8	1·80
	1·85	3·7	5·5	7·4	9·2	11·1	12·9	14·8	16·6	18·5	20·3	22·2	24·0	25·9	27·7	29·6	1·85
	1·90	3·8	5·7	7·6	9·5	11·4	13·3	15·2	17·1	19·0	20·9	22·8	24·7	26·6	28·5	30·4	1·90
	1·95	3·9	5·8	7·8	9·7	11·7	13·6	15·6	17·5	19·5	21·4	23·4	25·3	27·3	29·2	31·2	1·95
	2·00	4·0	6·0	8·0	10·0	12·0	14·0	16·0	18·0	20·0	22·0	24·0	26·0	28·0	30·0	32·0	2·00
	2·05	4·1	6·1	8·2	10·3	12·3	14·3	16·4	18·4	20·5	22·5	24·6	26·6	28·7	30·7	32·8	2·05
	2·10	4·2	6·3	8·4	10·5	12·6	14·7	16·8	18·9	21·0	23·1	25·2	27·3	29·4	31·5	33·6	2·10
	2·15	4·3	6·4	8·6	10·7	12·9	15·0	17·2	19·3	21·5	23·6	25·8	27·9	30·1	32·2	34·4	2·15
	2·20	4·4	6·6	8·8	11·0	13·2	15·4	17·6	19·8	22·0	24·2	26·4	28·6	30·8	33·0	35·2	2·20
	2·25	4·5	6·7	9·0	11·2	13·5	15·7	18·0	20·2	22·5	24·7	27·0	29·2	31·5	33·7	36·0	2·25
	2·30	4·6	6·9	9·2	11.5	13·8	16·1	18·4	20·7	23·0	25·3	27·6	29·9	32·2	34·5	36·8	2·30
	2·35	4·7	7·0	9·4	11·7	14·1	16·4	18·8	21·1	23·5	25·8	28·2	30·5	32·9	35·2	37·5	2·35
	2·40	4·8	7·2	9·6	12·0	14·4	16·8	19·2	21·6	24·0	26·4	28·8	31·2	33·6	36·0	38·4	2·40

TABLE IIA
Chronometer Corrections.

CORRECTION IN LONGITUDE FOR ERROR IN D.R. LATITUDE.

Nr. from Tab. II.	17′	18′	19′	20′	21′	22′	23′	24′	25′	26′	27′	28′	29′	30′	31′	Nr. from Tab. II.	Speed, Time, & Distance
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	mins.
0·05	0·8	0·9	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	0·05	3
0·10	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	0·10	6
0·15	2·5	2·7	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·9	4·0	4·2	4·3	4·5	4·6	0·15	9
0·20	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·7	6·0	6·2	0·20	12
0·25	4·2	4·5	4·7	5·0	5·2	5·5	5·7	6·0	6·2	6·5	6·7	7·0	7·2	7·5	7·7	0·25	15
0·30	5·1	5·4	5·7	6·0	6·3	6·6	6·9	7·2	7·5	7·8	8·1	8·4	8·7	9·0	9·3	0·30	18
0·35	5·9	6·3	6·6	7·0	7·3	7·7	8·0	8·4	8·7	9·1	9·4	9·8	10·1	10·5	10·8	0·35	21
0·40	6·8	7·2	7·6	8·0	8·4	8·8	9·2	9·6	10·0	10·4	10·8	11·2	11·6	12·0	12·4	0·40	24
0·45	7·6	8·1	8·5	9·0	9·4	9·9	10·3	10·8	11·2	11·7	12·1	12·6	13·0	13·5	13·9	0·45	27
0·50	8·5	9·0	9·5	10·0	10·5	11·0	11·5	12·0	12·5	13·0	13·5	14·0	14·5	15·0	15·5	0·50	30
0·55	9·3	9·9	10·4	11·0	11·5	12·1	12·6	13·2	13·7	14·3	14·8	15·4	15·9	16·5	17·0	0·55	33
0·60	10·2	10·8	11·4	12·0	12·6	13·2	13·8	14·4	15·0	15·6	16·2	16·8	17·4	18·0	18·6	0·60	36
0·65	11·0	11·7	12·3	13·0	13·6	14·3	14·9	15·6	16·2	16·9	17·5	18·2	18·8	19·5	20·1	0·65	39
0·70	11·9	12·6	13·3	14·0	14·7	15·4	16·1	16·8	17·5	18·2	18·9	19·6	20·3	21·0	21·7	0·70	42
0·75	12·7	13·5	14·2	15·0	15·7	16·5	17·2	18·0	18·7	18·5	20·2	21·0	21·7	22·5	23·2	0·75	45
0·80	13·6	14·4	15·2	16·0	16·8	17·6	18·4	19·2	20·0	20·9	21·6	22·4	23·2	24·0	24·8	0·80	48
0·85	14·4	15·3	16·1	17·0	17·8	18·7	19·5	20·4	21·2	22·1	22·9	23·8	24·6	25·5	26·3	0·85	51
0·90	15·3	16·2	17·0	18·0	18·9	19·8	20·7	21·6	22·5	23.4	24·3	25·2	26·1	27.0	27·9	0·90	54
0·95	16·1	17·1	18·0	19·0	19·9	20·9	21·8	22·8	23·7	24·7	25·6	26·6	27·5	28·5	29·4	0·95	57
1·00	17·0	18·0	19·0	20·0	21·0	22·0	23.0	24·0	25·0	26·0	27·0	28·0	29·0	30·0	31·0	1·00	
1·05	17·8	18·9	19·9	21·0	22·0	23·1	24·1	25·2	26·2	27·3	28·3	29·4	30·4	31·5	32·5	1·05	
1·10	18·7	19·8	20·9	22·0	23·1	24·2	25·3	26·4	27·5	28·6	29·7	30·8	31·9	33·0	34·1	1·10	
1·15	19·5	20·7	21·8	23·0	24·1	25·3	26·4	27·6	28·7	29·9	31·0	32·2	33·3	34·5	35·6	1·15	
1·20	20·4	21·6	22·8	24·0	25·2	26·4	27·6	28·8	30·0	31·2	32·4	33·6	34·8	36·0	37·2	1·20	
1·25	21·2	22·5	23·7	25·0	26·2	27·5	28·7	30·0	31·2	32·5	33·7	35·0	36·2	37·5	38·7	1·25	
1·30	22·1	23·4	24·7	26·0	27·3	28·6	29·9	31·2	32·5	33·8	35·1	36·4	37·7	39·0	40·3	1·30	
1·35	22·9	24·3	25·6	27·0	28·3	29·7	31·0	32·4	33·7	35·1	36·4	37·8	39·1	40·5	41·8	1·35	
1·40	23·8	25·2	26·6	28·0	29·4	30·8	32·2	33·6	35·0	36·4	37·8	39·2	40·6	42·0	43·4	1·40	
1·45	24·6	26·1	27·5	29·0	30·4	31·9	33·3	34·8	36·2	37·7	39·1	40·6	42·0	43·5	44·9	1·45	
1·50	25·5	27·0	28·5	30·0	31·5	33·0	34·5	36·0	37·5	39·0	40·5	42·0	43·5	45·0	46·5	1·50	
1·55	26·3	27·9	29·4	31·0	32·5	34·1	35·6	37·2	38·7	40·3	41·8	43·4	44·9	46·5	48·0	1·55	
1·60	27·2	28·8	30·4	32·0	33·6	35·2	36·8	38·4	40·0	41·6	43·2	44·8	46·4	48·0	49·6	1·60	
1·65	28·0	29·7	31·3	33·0	34·6	36·3	37·9	39·6	41·2	42·9	44·5	46·2	47·8	49·5	51·1	1·65	
1·70	28·9	30·6	32·3	34·0	35·7	37·4	39·1	40·8	42·5	44·2	45·9	47·6	49·3	51·0	52·7	1·70	
1·75	29·7	31·5	33·2	35·0	36·7	38·5	40·2	42·0	43·7	45·5	47·2	49·0	50·7	52·5	54·2	1·75	
1·80	30·6	32·4	34·2	36·0	37·8	39·6	41·4	43·2	45·0	46·8	48·5	50·4	52·2	54·0	55·8	1·80	
1·85	31·4	33·3	35·1	37·0	38·8	40·7	42·5	44·4	46·2	48·1	49·9	51·8	53·6	55·5	57·3	1·85	
1·90	32·3	34·2	36·1	38·0	39·9	41·8	43·7	45·6	47·5	49·4	51·3	53·2	55·1	57·0	58·9	1·90	
1·95	33·1	35·1	37·0	39·0	40·9	42·9	44·8	46·8	48·7	50·7	52·6	54·6	56·5	58·5	60·4	1·95	
2·00	34·0	36·0	38·0	40·0	42·0	44·0	46·0	48·0	50·0	52·0	54·0	56·0	58·0	60·0	62·0	2·00	
2·05	34·8	36·9	38·9	41·0	43·0	45·1	47·1	49·2	51·2	53·3	55·3	57·4	59·4	61·5	63·5	2·05	
2·10	35·7	37·8	39·9	42·0	44·1	46·2	48·3	50·4	52·5	54·6	56·7	58·8	60·9	63·0	65·1	2·10	
2·15	36·5	38·7	40·8	43·0	45·1	47·3	49·4	51·6	53·7	55·9	58·0	60·2	62·3	64·5	66·6	2·15	
2·20	37·4	39·6	41·8	44·0	46·2	48·4	50·6	52·8	55·0	57·2	59·4	61·6	63·8	66·0	68·2	2·20	
2·25	38·2	40·5	42·7	45·0	47·2	49·5	51·7	54·0	56·2	58·5	60·7	63·0	65·3	67·5	69·7	2·25	
2·30	39·1	41·4	43·7	46·0	48·2	50·6	52·9	55·2	57·5	59·8	62·1	64·4	66·7	69·0	71·3	2·30	
2·35	39·9	42·3	44·6	47·0	49·3	51·7	54·1	56·4	58·7	61·1	63·4	65·8	68·1	70·5	72.9	2·35	
2·40	40·8	43·2	45·6	48·0	50·4	52·8	55·2	57·6	60·0	62·4	64·8	67·2	69·6	72·0	74.4	2·40	

TABLE III.
EX-MERIDIAN TABLE.

	Latitude.															
Alt.	0°	4°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	32°	34°
°	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
8	1·01	1·01	1·00	1·00	0·99	0·98	0·97	0·96	0·95	0·94	0·92	0·91	0·89	0·88	0·86	0·84
10	1·01	1·01	1·00	1·00	0·99	0·98	0·97	0·96	0·95	0·94	0·92	0·91	0·89	0·88	0·86	0·84
12	1·02	1·02	1·01	1·01	1·00	0·99	0·98	0·97	0·96	0·95	0·93	0·91	0·90	0·88	0·87	0·85
14	1·03	1·03	1·02	1·02	1·01	1·00	0·99	0·98	0·97	0·96	0·94	0·92	0·91	0·89	0·87	0·85
16	1·04	1·04	1·03	1·03	1·02	1·01	1·00	0·99	0·98	0·97	0·95	0·94	0·92	0·90	0·88	0·86
18	1·05	1·05	1·04	1·04	1·03	1·02	1·01	1·00	0·99	0·98	0·96	0·95	0·93	0·91	0·89	0·87
20	1·06	1·06	1·05	1·05	1·04	1·03	1·02	1·01	1·00	0·99	0·97	0·96	0·94	0·92	0·90	0·88
22	1·07	1·07	1·06	1·06	1·05	1·04	1·03	1·02	1·01	1·00	0·98	0·97	0·95	0·93	0·91	0·89
24	1·09	1·09	1·08	1·08	1·07	1·06	1·05	1·04	1·02	1·01	1·00	0·98	0·96	0·94	0·92	0·90
26	1·11	1·11	1·10	1·09	1·08	1·08	1·07	1·06	1·04	1·03	1·01	1·00	0·98	0·96	0·94	0·92
28	1·13	1·13	1·12	1·11	1·10	1·10	1·09	1·08	1·06	1·05	1·03	1·02	1·00	0·98	0·96	0·94
30	1·15	1·15	1·14	1.13	1·12	1·12	1·11	1·10	1·08	1·07	1·05	1·04	1·02	1·00	0·98	0·96
32	1·18	1·18	1·17	1·16	1·15	1·14	1·13	1·12	1·11	1·10	1·08	1·06	1·04	1·02	1·00	0·98
34	1·21	1·21	1·20	1·19	1·18	1·16	1·16	1·15	1·13	1·12	1·10	1·08	1·06	1·05	1·02	1·00
36	1·24	1·24	1·23	1·22	1·21	1·20	1·19	1·18	1·16	1·15	1·13	1·11	1·09	1·07	1·06	1·03
38	1·27	1·27	1·26	1·25	1·24	1·23	1·22	1·21	1·19	1·18	1·16	1·14	1·12	1·10	1·08	1·06
40	1·31	1·31	1·30	1·29	1·28	1·27	1·26	1·25	1·23	1·21	1·20	1·18	1·16	1·14	1·11	1·09
42	1·35	1·35	1·34	1·33	1·32	1·31	1·30	1·29	1·27	1·25	1·23	1·21	1·19	1·17	1·14	1·12
44	1·39	1·39	1·38	1·37	1·36	1·35	1·34	1·33	1·31	1·29	1·27	1·25	1·23	1·21	1·18	1·15
46	1·44	1·44	1·43	1·42	1·41	1·40	1·38	1·37	1·35	1·33	1·31	1·29	1·27	1·25	1·22	1·19
48	1·49	1·49	1·48	1·47	1·46	1·45	1·43	1·42	1·40	1·38	1·36	1·34	1·32	1·29	1·26	1·24
50	1·55	1·55	1·54	1·53	1·52	1·51	1·49	1·48	1·46	1·44	1·42	1·40	1·37	1·34	1·31	1·29
52	1·62	1·62	1·60	1·59	1·58	1·57	1·56	1·54	1·52	1·50	1·48	1·46	1·43	1·40	1·37	1·34
54	1·70	1·70	1·68	1·68	1·66	1·65	1·64	1·62	1·59	1·58	1·56	1·53	1·50	1·46	1·44	1·41
56	1·79	1·79	1·77	1·76	1·75	1·74	1·72	1·70	1·68	1·66	1·64	1·61	1·58	1·55	1·52	1·49
58	1·89	1·89	1·87	1·86	1·85	1·84	1·82	1·80	1·78	1·76	1·73	1·70	1·67	1·63	1·61	1·58
60	2·00	2·00	1·98	1·97	1·96	1·94	1·92	1·90	1·88	1·86	1·83	1·80	1·77	1·74	1·70	1·66
62	2·13	2·12	2·11	2·10	2·08	2·07	2·05	2·03	2·00	1·97	1·95	1·91	1·88	1·84	1·81	1·77
64	2·28	2·27	2·26	2·24	2·23	2·21	2·19	2·17	2·14	2·11	2·08	2·05	2·01	1·97	1·93	1·89

	Minutes of Hour-Angle.												[Reduction.			
N.	5m	6m	7m	8m	9m	10m	11m	12m	13m	14m	15m	16m	17m	18m	19m	20m
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
0·50	0·4	0·5	0·8	1·0	1·3	1·6	2·0	2·3	2·7	3·2	3·7	4·2	4·7	5·3	5·9	6·5
0·55	0·4	0·6	0·9	1·1	1·4	1·8	2·3	2·5	3·0	3·5	4·0	4·6	5·2	5·8	6·5	7·2
0·60	0·5	0·7	1·0	1·3	1·6	2·0	2·4	2·8	3·3	3·8	4·4	5·0	5·7	6·4	7·1	7·9
0·65	0·5	0·7	1·0	1·4	1·7	2·1	2·6	3·0	3·5	4·1	4·8	5·4	6·1	6·9	7·7	8·5
0·70	0·6	0·8	1·1	1·5	1·8	2·3	2·8	3·3	3·8	4·5	5·2	5·9	6·6	7·4	8·3	9·2
0·75	0·6	0·8	1·2	1·6	1·9	2·4	3·0	3·5	4·1	4·8	5·5	6·3	7·1	7·9	8·8	9·8
0·80	0·6	0·9	1·3	1·7	2·1	2·6	3·2	3·8	4·4	5·1	5·9	6·7	7·6	8·5	9·4	10·4
0·85	0·7	0·9	1·3	1·8	2·2	2·8	3·4	4·0	4·6	5·4	6·2	7·1	8·0	9·0	10·0	11·0
0·90	0·7	1·0	1·4	1·9	2·3	3·1	3·6	4·2	4·9	5·8	6·6	7·5	8·5	9·5	10·6	11·7
0·95	0·7	1·0	1·5	2·0	2·4	3·2	3·8	4·4	5·2	6·1	7·0	7·9	9·0	10·0	11·2	12·3
1·00	0·8	1·1	1·6	2·1	2·6	3·3	4·0	4·7	5·5	6·4	7·4	8·4	9·5	10·6	11·8	13·0
1·05	0·8	1·1	1·7	2·2	2·7	3·4	4·2	4·9	5·7	6·8	7·7	8·8	9·9	11·1	12·4	13·6
1·10	0.9	1·2	1·8	2·3	2·8	3·6	4·4	5·1	6·0	7·0	8·1	9·2	10·4	11·7	13·0	14·3
1·15	1·0	1·3	1·9	2·4	3·0	3·8	4·6	5·3	6·3	7·4	8·5	9·6	10·9	12·2	13·6	15·0
1.20	1·0	1·3	1.9	2·5	3·2	4·0	4·8	5·6	6·6	7·7	8·9	10·1	11·4	12·7	14·2	15·7
1·25	1·0	1·4	2·0	2·6	3·3	4·1	5·0	5·8	6·8	8·0	9·2	10·5	11·8	13·2	14·7	16·3

For Lat. or Alt. above 60° *see* Table (iii.), p. 35

TABLE III.

EX-MERIDIAN TABLE

Alt.	LATITUDE. 34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	60°
°	N	N	N	N	N	N	N	N	N	N	N	N	N	N
8	0·84	0·82	0·80	0·77	0·75	0·73	0·71	0·68	0·65	0·62	0·59	0·56	0·53	0·50
10	0·84	0·82	0·80	0·77	0·75	0·73	0·71	0·68	0·65	0·62	0·59	0·56	0·53	0·50
12	0·85	0·82	0·80	0·78	0·76	0·73	0·71	0·68	0·66	0·63	0·60	0·57	0·54	0·51
14	0·86	0·83	0·81	0·79	0·77	0·74	0·72	0.69	0·66	0·63	0·60	0·57	0·54	0·51
16	0·86	0·84	0·82	0·80	0·78	0·75	0·73	0.70	0·67	0·64	0·61	0·58	0·55	0·52
18	0·87	0·85	0·82	0·80	0·78	0·75	0·73	0.70	0·67	0·64	0·61	0·58	0·55	0·52
20	0·88	0·86	0·84	0·81	0·79	0·76	0·74	0.71	0·68	0·65	0·62	0·59	0·56	0·53
22	0·89	0·87	0·85	0·82	0·80	0·77	0·75	0.72	0·69	0·66	0·63	0·60	0·57	0·53
24	0·90	0·88	0·86	0·83	0·81	0·78	0·76	0.73	0·70	0·67	0·64	0·61	0·58	0·54
26	0·92	0·89	0·87	0·85	0·82	0·79	0·77	0.74	0·71	0·68	0·65	0·62	0·59	0·55
28	0·94	0·91	0·89	0·87	0·84	0·81	0·79	0.76	0·73	0·70	0·67	0·63	0·60	0·56
30	0·96	0·93	0·91	0·88	0·86	0·83	0·80	0.77	0·74	0·71	0·68	0·64	0·61	0·57
32	0·98	0·96	0·93	0·90	0·88	0·85	0·82	0·79	0·76	0·73	0·70	0·66	0·63	0·59
34	1·00	0·98	0·95	0·92	0·90	0·87	0·84	0·81	0·78	0·74	0·71	0·67	0·64	0·60
36	1·03	1·00	0·98	0·95	0·92	0·89	0·87	0·83	0·80	0·76	0·73	0·69	0·65	0·62
38	1·06	1·03	1·00	0·97	0·94	0·91	0·88	0·85	0·82	0·78	0·75	0·71	0·67	0.63
40	1·09	1·06	1·03	1·00	0·97	0·94	0·91	0·88	0·85	0·81	0·77	0·73	0·69	0·65
42	1·12	1·09	1·06	1·03	1·00	0·97	0·94	0·90	0·87	0·83	0·79	0·75	0·71	0·67
44	1·15	1·12	1·09	1·06	1·03	1·00	0·97	0·93	0·90	0·86	0·82	0·78	0·74	0·69
46	1·19	1·16	1·13	1·10	1·07	1·03	1·00	0·96	0·93	0·89	0·85	0·80	0·76	0·71
48	1·24	1·21	1·18	1·14	1·11	1·07	1·03	1·00	0·97	0·92	0·88	0·83	0·79	0·74
50	1·29	1·26	1·23	1·19	1·15	1·11	1·08	1·04	1·00	0.96	0·92	0·87	0·82	0·77
52	1·34	1·31	1·28	1·24	1·20	1·16	1·12	1·08	1·04	1.00	0·96	0·91	0·86	0·81
54	1·41	1·38	1·34	1·29	1·26	1·22	1·18	1·14	1·10	1.05	1·00	0·95	0·90	0·85
56	1·49	1·45	1·41	1·37	1·33	1·29	1·25	1·20	1·15	1·10	1·05	1·00	0·95	0·89
58	1·57	1·53	1·49	1·45	1·41	1·36	1·32	1·27	1·21	1·16	1·11	1·06	1·00	0·94
60	1·66	1·62	1·58	1·53	1·49	1·44	1·39	1·34	1·29	1·23	1·18	1·12	1·06	1·00
62	1·77	1·73	1·69	1.64	1·59	1·54	1·48	1·38	1·33	1·31	1·26	1·19	1·13	1·07
64	1·89	1·84	1·80	1.75	1·69	1·64	1·58	1·53	1·47	1·40	1·34	1·27	1·21	1·14

Second Correction

Dec.	Reduction 5′	10′	15′
°	′	′	′
4	0·0	0.0	0·0
8	0·0	0·1	0·1
10	0·1	0·2	0·2
12	0·1	0·2	0·3
14	0·1	0·3	0·4
16	0·2	0·4	0·6
18	0·2	0.5	0·7
20	0·3	0.6	0·9
22	0·4	0.7	1·1
24	0·4	0·9	1·3
26	0·5	1·0	1·5
28	0·6	1·2	1·8

Dec.	Reduction 20′	25′	30′
°	′	′	′
4	0·0	0·1	0·1
8	0·2	0·2	0·3
10	0·3	0·4	0·5
12	0·4	0·5	0·7
14	0·6	0·7	0·9
16	0·8	1·0	1·2
18	1·0	1·2	1·5
20	1·2	1·5	1·8
22	1·5	1·8	2·2
24	1·7	2·2	2·6
26	2·0	2·5	3·0
28	2·3	2·9	3·5

MINUTES OF HOUR-ANGLE [REDUCTION ·

N.	5m	6m	7m	8m	9m	10m	11m	12m	13m	14m	15m	16m	17m	18m	19m	20m
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
1·25	1·0	1·4	2·0	2·6	3·3	4·1	5·0	5·8	6·8	8·0	9·2	10·5	11·8	13·2	14·7	16·3
1·30	1·0	1·4	2·1	2·7	3·4	4·3	5·2	6·1	7·1	8·3	9·6	10·9	12·3	13·8	15·3	17·0
1·35	1·0	1·4	2·1	2·8	3·5	4·4	5·4	6·3	7·4	8·6	10·0	11·3	12·8	14·3	15·9	17·6
1·40	1·1	1·5	2·2	2·9	3·6	4·6	5·6	6·6	7·7	9·0	10·4	11·9	13·3	14·8	16·5	18·3
1·45	1·1	1·5	2·3	3·0	3·7	4·7	5·8	6·8	7·9	9·3	10·7	12·2	13·7	15·3	17·1	18·9
1·50	1·2	1·6	2·4	3·1	3·9	4·9	6·0	7·0	8·2	9·6	11·1	12·6	14·2	15·9	17·7	19·6
1·55	1·2	1·7	2·5	3·2	4·0	5·1	6·2	7·2	8·5	9·9	11·4	13·0	14·7	16·4	18·3	20·3
1·60	1·2	1·8	2·6	3·4	4·2	5·3	6·4	7·5	8·8	10·2	11·8	13·4	15·2	17·0	18·9	21·0
1·65	1·3	1·8	2·6	3·5	4·3	5·4	6·6	7·7	9·0	10·5	12·2	13·8	15·6	17·5	19·5	21·6
1·70	1·4	1·9	2·7	3·6	4·4	5·6	6·8	8·0	9·3	10·9	12·6	14·3	16·1	18·0	20·1	22·2
1·75	1·4	1·9	2·8	3·7	4·5	5·7	7·0	8·2	9·6	11·2	12·9	14·7	16·5	18·5	20·6	22·8
1·80	1·4	2·0	2·9	3·8	4·7	5·9	7·2	8·5	9·9	11·5	13·3	15·1	17·0	19·1	21·2	23·8
1·85	1·4	2·0	2·9	3·9	4·8	6·1	7·4	8·7	10·1	11·8	13·7	15·5	17·5	19·6	21·8	24·1
1·90	1·5	2·1	3·0	4·0	4·9	6·3	7·6	8·9	10·4	12·1	14·1	16·0	18·0	20·1	22·4	24·8
1·95	1·5	2·1	3·1	4·1	5·0	6·4	7·8	9·1	10·7	12·4	14·4	16·4	18·5	20·6	23·0	25·5
2·00	1·6	2·2	3·2	4·2	5·2	6·6	8·0	9·4	11·0	12·8	14·8	16·8	19·0	21·2	23·6	26·2

For Lat. or Alt. above 60° *see* Table (iii.), p. 35

TABLE III.

Ex-Meridian (contd.)

N	Minutes of Hour-Angle															
	M 20	M 21	M 22	M 23	M 24	M 25	M 26	M 27	M 28	M 29	M 30	M 31	M 32	M 33	M 34	M 35
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
0·50	6·5	7·2	7·9	8·6	9·5	10·2	11·1	12·0	12·9	13·8	14·7	15·7	16·8	17·8	18·9	20·1
0·55	7·2	8·0	8·7	9·5	10·4	11·3	12·2	13·2	14·1	15·1	16·2	17·3	18·4	19·6	20·8	22·2
0·60	7·9	8·7	9·5	10·4	11·3	12·3	13·3	14·4	15·4	16·5	17·7	18·9	20·2	21·4	22·8	24·2
0·65	8·5	9·4	10·3	11·2	12·2	13·3	14·4	15·6	16·7	17·9	19·1	20·4	21·8	23·2	24·6	26·2
0·70	9·2	10·1	11·1	12·1	13·2	14·3	15·5	16·8	17·9	19·3	20·6	22·0	23·6	25·0	26·6	28·2
0·75	9·8	10·9	11·9	12·9	14·1	15·4	16·6	18·0	19·2	20·6	22·1	23·6	25·2	26·8	28·4	30·2
0·80	10·4	11·6	12·7	13·8	15·1	16·4	17·8	19·2	20·5	22·0	23·6	25·2	26·8	28·6	30·4	32·2
0·85	11·0	12·3	13·5	14·6	16·0	17·4	18·9	20·4	21·8	23·4	25·0	26·7	28·4	30·2	32·2	34·2
0·90	11·7	13·0	14·3	15·5	17·0	18·4	20·0	21·6	23·1	24·8	26·5	28·3	30·2	32·0	34·0	36·2
0·95	12·3	13·8	15·1	16·4	17·9	19·5	21·1	22·8	24·4	26·2	28·0	29·9	31·8	33·8	36·0	38·2
1·00	13·0	14·4	15·9	17·3	18·9	20·5	22·2	24·0	25·7	27·6	29·5	31·5	33·6	35·6	38·0	40·2
1·05	13·6	15·2	16·7	18·1	19·8	21·5	23·3	25·2	27·0	28·9	30·9	33·0	35·4	37·4	39·8	42·2
1·10	14·3	15·9	17·5	19·0	20·8	22·5	24·4	26·4	28·3	30·3	32·4	34·7	37·0	39·2	41·8	44·2
1·15	15·0	16·7	18·3	19·8	21·7	23·6	25·5	27·6	29·6	31·7	33·9	36·2	38·6	41·0	43·6	46·2
1·20	15·7	17·3	19·1	20·8	22·7	24·6	26·6	28·8	30·9	33·1	35·4	37·9	40·4	42·8	45·6	48·2
1·25	16·3	18·1	19·9	21·6	23·6	25·6	27·7	30·0	32·2	34·4	36·8	39·5	42·0	44·6	47·4	50·2
1·30	17·0	18·8	20·7	22·5	24·6	26·6	28·9	31·2	33·5	35·8	38·3	40·9	43·6	46·2	49·4	52·2
1·35	17·6	19·6	21·5	23·3	25·5	27·7	30·0	32·4	34·7	37·2	39·8	42·5	45·2	48·0	51·2	54·2
1·40	18·3	20·3	22·3	24·2	26·5	28·7	31·1	33·6	36·0	38·6	41·3	44·1	47·0	49·8	53·2	56·2
1·45	18·9	20·9	23·1	25·0	27·4	29·7	32·2	34·8	37·3	40·0	42·7	45·6	48·6	51·4	55·0	58·2
1·50	19·6	21·7	23·9	25·9	28·4	30·7	33·3	36·0	38·6	41·4	44·2	47·2	50·2	53·4	57·0	60·2
1·55	20·3	22·5	24·7	26·8	29·3	31·8	34·4	37·2	39·8	42·7	45·7	48·8	52·0	55·2	58·8	62·3
1·60	21·0	23·2	25·5	27·7	30·2	32·8	35·5	38·4	41·1	44·2	47·2	50·4	53·8	57·0	60·8	64·4
1·65	21·6	23·9	26·3	28·5	31·1	33·8	36·6	39·6	42·4	45·5	48·6	51·9	55·4	58·8	62·6	66·4
1·70	22·2	24·7	27·1	29·4	32·1	34·8	37·8	40·8	43·7	46·9	50·1	53·5	57·2	60·8	64·6	68·4
1·75	22·8	25·4	27·9	30·2	33·1	35·8	38·9	42·0	45·0	48·2	51·6	55·1	58·8	62·4	66·4	70·4
1·80	23·4	26·1	28·7	31·1	34·0	36·9	40·0	43·2	46·3	49·5	53·1	56·7	60·4	64·0	68·4	72·4
1·85	24·1	26·8	29·5	31·9	34·9	37·9	41·1	44·4	47·5	50·9	54·5	58·2	62·0	65·8	70·2	74·4
1·90	24·8	27·5	30·3	32·8	35·9	38·9	42·2	45·6	48·8	52·4	56·0	59·8	63·8	67·6	72·2	76·4

	Second Correction												[Reduction			
DEC	35′	40′	45′	50′	55′	60′	62′	64′	66′	68′	70′	72′	74′	76′	78′	80′
4	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2
8	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·7	0·7	0·8	0·8
10	0·5	0·6	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·1	1·2	1·2	1·2
12	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·4	1·4	1·5	1·5	1·6	1·6	1·7	1·7	1·7
14	1·0	1·2	1·3	1·5	1·6	1·8	1·8	1·9	2·0	2·0	2·1	2·1	2·2	2·3	2·3	2·4
16	1·4	1·5	1·7	1·9	2·1	2·3	2·4	2·5	2·6	2·6	2·7	2·8	2·9	2·9	3·0	3·1
18	1·7	2·0	2·2	2·4	2·7	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9
20	2·1	2·4	2·7	3·0	3·3	3·6	3·7	3·9	4·0	4·1	4·2	4·3	4·5	4·6	4·7	4·8
22	2·5	2·9	3·3	3·6	4·0	4·4	4·5	4·7	4·8	5·0	5·1	5·2	5·4	5·5	5·7	5·8
24	3·0	3·5	3·9	4·3	4·8	5·2	5·4	5·5	5·7	5·9	6·1	6·2	6·4	6·6	6·7	6·9
26	3·5	4·0	4·6	5·1	5·6	6·1	6·3	6·5	6·7	6·9	7·1	7·3	7·5	7·7	7·9	8·1
28	4·1	4·7	5·3	5·9	6·4	7·0	7·3	7·5	7·7	8·0	8·2	8·4	8·7	8·9	9·1	9·4

Note.—Should the Hour-Angle exceed 35m. take out the correction for its half and multiply it by 4.

SUPPLEMENTARY TABLES.

(i.) Extension of Table I. to Lat. or Dec. 80°.

For Lat.	60°	62°	63°	64°	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°	76°	77°	78°	79°	80°
Take Lat.	41°	43°	44°	45°	47°	48°	50°	51°	52°	54°	55°	57°	58°	49°	51°	53°	56°	58°	46°	48°
And Mult. Nr. by	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	5	5

(ii.) Extension of Table II. to Lat. 80°.

For Lat.	61°	62°	63°	64°	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°	76°	77°	78°	79°	80°
Take Lat.	14°	20°	25°	29°	32°	35°	38°	41°	44°	47°	50°	52°	54°	56°	39°	44°	47°	50°	55°	59°
And Mult. Corr. by	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3

(iii.) Extension of Ex-Meridian Table to Lat. 80° or Alt. 80°.

For Lat.	61°	62°	63°	64°	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°	76°	77°	78°	79°	80°
Take Lat.	18°	22°	27°	30°	33°	36°	40°	43°	46°	48°	50°	52°	54°	56°	58°	45°	48°	52°	56°	60°
And Div. Redn. by	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3
For Alt.	61°	62°	63°	64°	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°	76°	77°	78°	79°	80°
Take Alt.	14°	20°	25°	29°	32°	35°	38°	42°	44°	47°	50°	52°	54°	56°	59°	43°	47°	53°	55°	58°
And Mult. Redn. by	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3

FOR COMBINED EX-MERIDIANS.

(iv.) Lesser Hour-Angle

Interval. M	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19	M 20
10	0·50	0·60	0·70	0·80	0·90	1·00	1·10	1·20	1·30	1·40	1·50	1·60	1·70	1·80	1·90	2·00
12	0·42	0·50	0·58	0·66	0·75	0·83	0·91	0·99	1·08	1·16	1·24	1·33	1·41	1·49	1·58	1·66
14	0·36	0·43	0·50	0·58	0·65	0·72	0·79	0·85	0·93	1·01	1·08	1·15	1·21	1·28	1·36	1·43
16	0·31	0·37	0·43	0·49	0·55	0·62	0·68	0·74	0·80	0·87	0·94	1·00	1·06	1·11	1·19	1·25
18	0·28	0·34	0·39	0·45	0·50	0·56	0·62	0·67	0·73	0·78	0·84	0·89	0·95	1·01	1·06	1·12
20	0·25	0·30	0·35	0·40	0·45	0·50	0·55	0·60	0·65	0·70	0·75	0·80	0·85	0·90	0·95	1·00
22	0·22	0·26	0·31	0·35	0·39	0·44	0·48	0·53	0·57	0·61	0·66	0·70	0·75	0·79	0·83	0·88
24	0·20	0·24	0·28	0·33	0·37	0·41	0·45	0·49	0·53	0·57	0·61	0·65	0·69	0·73	0·77	0·81
26	0·19	0·22	0·26	0·30	0·34	0·37	0·41	0·45	0·49	0·52	0·56	0·60	0·65	0·69	0·73	0·77
28	0·17	0·21	0·24	0·27	0·31	0·34	0·38	0·41	0·44	0·48	0·51	0·55	0·58	0·62	0·65	0·68
30	0·16	0·20	0·23	0·27	0·30	0·33	0·37	0·40	0·43	0·47	0·50	0·53	0·57	0·60	0·63	0·67

Note.—Should either the Hour-Angle or interval exceed the limit of the table, enter it with the half or third of both. Thus for H. A. 18m. and interval 48m. we have 9m. and 24m. which give ·37.

(IV.)				LOG-SECANTS.										PARTS FOR MINUTES.								
Deg	0′	10′	20′	30′	40′	50′	Deg	0′	10′	20′	30′	40′	50′	1′	2′	3′	4′	5′	6′	7′	8′	9′
0°	0·0000	0000	0000	0000	0000	0000	1°	0·0001	0001	0001	0001	0001	0002	0	0	0	0	0	0	0	1	1
2	0·0003	0003	0004	0004	0005	0005	3	0·0006	0007	0007	0008	0009	0010	0	0	0	0	0	0	1	1	1
4	0·0011	0011	0012	0013	0014	0015	5	0·0017	0018	0019	0020	0021	0023	0	0	0	0	0	1	1	1	1
6	0·0024	0025	0027	0028	0029	0031	7	0·0032	0034	0036	0037	0039	0041	0	0	0	1	1	1	1	1	1
8	0·0042	0044	0046	0048	0050	0052	9	0·0054	0056	0058	0060	0062	0064	0	0	1	1	1	1	1	2	2
10	0·0066	0069	0071	0073	0076	0078	11	0·0081	0083	0086	0089	0091	0093	0	0	1	1	1	2	2	2	2
12	0·0096	0099	0101	0104	0107	0110	13	0·0113	0116	0119	0122	0125	0128	0	1	1	1	1	2	2	2	3
14	0·0131	0134	0137	0141	0144	0147	15	0·0151	0154	0157	0161	0164	0168	0	1	1	1	2	2	2	3	3
16	0·0172	0175	0179	0183	0186	0190	17	0·0194	0198	0202	0206	0210	0214	0	1	1	1	2	2	2	3	3
18	0·0218	0222	0226	0230	0235	0239	19	0·0243	0248	0252	0257	0261	0266	0	1	1	2	2	2	3	3	3
20	0·0270	0275	0279	0284	0289	0294	21	0·0298	0303	0308	0313	0318	0323	0	1	1	2	2	3	3	4	4
22	0·0328	0334	0339	0344	0349	0354	23	0·0360	0365	0371	0376	0382	0387	1	1	2	2	3	3	4	4	5
24	0·0393	0398	0404	0410	0416	0421	25	0·0427	0433	0439	0445	0451	0457	1	1	2	2	3	3	4	5	5
26	0·0463	0470	0476	0482	0488	0495	27	0·0501	0508	0514	0521	0527	0534	1	1	2	3	3	4	4	5	6
28	0·0541	0547	0554	0561	0568	0575	29	0·0582	0589	0596	0603	0610	0617	1	1	2	3	3	4	5	6	6
30	0·0625	0632	0639	0647	0654	0662	31	0·0669	0677	0685	0692	0700	0708	1	2	2	3	4	5	5	6	7
32	0·0716	0724	0732	0740	0748	0756	33	0·0764	0772	0781	0789	0797	0806	1	2	2	3	4	5	6	6	7
34	0·0814	0823	0831	0840	0849	0858	35	0·0866	0875	0884	0893	0902	0911	1	2	3	3	4	5	6	7	8
36	0·0920	0930	0939	0948	0958	0967	37	0·0976	0986	0996	1005	1015	1025	1	2	3	4	5	6	7	8	9
38	0·1035	1045	1055	1065	1075	1085	39	0·1095	1105	1116	1126	1136	1147	1	2	3	4	5	6	7	8	9
40	0·1157	1168	1179	1190	1200	1211	41	0·1222	1233	1244	1255	1267	1278	1	2	3	4	5	7	8	9	10
42	0·1289	1301	1312	1324	1335	1347	43	0·1359	1371	1382	1394	1406	1418	1	2	4	5	6	7	8	9	11
44	0·1431	1443	1455	1468	1480	1493	45	0·1505	1518	1531	1543	1556	1569	1	2	4	5	6	7	9	10	11
46	0·1582	1595	1609	1622	1635	1649	47	0·1662	1676	1689	1703	1717	1731	1	3	4	5	7	8	9	11	12
48	0·1745	1759	1773	1787	1802	1816	49	0·1831	1845	1860	1875	1889	1904	2	3	5	6	7	9	10	12	13
50	0·1919	1934	1950	1965	1980	1996	51	0·2011	2027	2043	2058	2074	2090	2	3	5	6	8	9	11	12	14
52	0·2107	2123	2139	2156	2172	2189	53	0·2205	2222	2239	2256	2273	2290	2	3	5	7	8	10	12	13	15
54	0·2308	2325	2343	2360	2378	2396	55	0·2414	2432	2450	2469	2487	2506	2	4	5	7	9	11	13	14	16
56	0·2524	2543	2562	2581	2600	2620	57	0·2639	2658	2678	2698	2718	2738	2	4	6	8	10	12	14	16	18
58	0·2758	2778	2799	2819	2840	2861	59	0·2882	2903	2924	2945	2967	2988	2	4	6	8	10	13	15	17	19
60	0·3010	3032	3054	3077	3099	3122	61	0·3144	3167	3190	3213	3237	3260	2	5	7	9	11	14	16	18	21
62	0·3284	3308	3332	3356	3380	3405	63	0·3429	3454	3479	3505	3530	3556	2	5	7	10	12	15	17	20	22
64	0·3582	3608	3634	3660	3687	3714	65	0·3741	3768	3795	3823	3851	3879	3	5	8	11	13	16	19	22	24
66	0·3907	3935	3964	3993	4022	4052	67	0·4081	4111	4141	4172	4202	4233	3	6	9	12	15	18	21	24	27
68	0·4264	4296	4327	4359	4391	4424	69	0·4457	4490	4523	4557	4591	4625	3	7	10	13	16	20	23	26	30

	0′	5′	10′	15′	20′	25′	1′	2′	3′	4′	30′	35′	40′	45′	50′	55′	1′	2′	3′	4′
70°	0·4659	4677	4694	4712	4730	4747	4	7	11	14	0·4765	4783	4801	4819	4837	4855	4	7	11	15
71	0·4874	4892	4910	4929	4948	4966	4	7	11	15	0·4985	5004	5023	5042	5061	5081	4	8	11	15
72	0·5100	5120	5139	5159	5179	5199	4	8	12	16	0·5219	5239	5259	5279	5300	5320	4	8	12	16
73	0·5341	5361	5382	5403	5424	5445	4	8	12	16	0·5467	5488	5509	5531	5553	5575	4	9	13	17
74	0·5597	5619	5641	5663	5686	5708	5	9	13	18	0·5731	5754	5777	5800	5823	5847	5	9	14	19
75	0·5870	5894	5917	5941	5965	5990	5	10	14	19	0·6014	6038	6063	6088	6113	6138	5	10	15	20
76	0·6163	6189	6214	6240	6266	6292	5	10	16	21	0·6318	6345	6371	6398	6425	6452	5	11	16	22
77	0·6479	6507	6534	6562	6590	6618	6	11	17	22	0·6647	6675	6704	6733	6762	6792	6	12	17	23
78	0·6821	6851	6881	6911	6942	6973	6	12	18	24	0·7003	7035	7066	7098	7130	7162	6	13	19	25
79	0·7194	7227	7260	7293	7326	7358	7	13	20	26	0·7394	7428	7462	7497	7532	7568	7	14	21	28
80	0·7603	7639	7676	7712	7749	7786	7	15	22	30	0·7824	7862	7900	7939	7978	8017	8	15	23	31
81	0·8057	8097	8137	8178	8219	8261	8	16	24	33	0·8303	8345	8388	8432	8475	8520	9	17	26	35
82	0·8564	8610	8655	8701	8748	8795	9	18	28	37	0·8843	8891	8940	8989	9039	9090	10	20	30	39
83	0·9141	9193	9245	9298	9352	9406	11	21	32	42	0·9461	9517	9574	9631	9689	9748	11	23	34	46
84	0·9808	9868	9930	9992	1·0055	0119	12	25	37	50	1·0184	0250	0318	0386	0455	0525	14	27	41	55
85	1·0597	0670	0744	0819	0896	0974	15	30	45	60	1·1054	1138	1217	1301	1387	1475	17	34	50	67
86	1·1564	1655	1749	1844	1941	2041	19	38	57	76	1·2143	2248	2355	2465	2577	2693	22	44	66	88
87	1·2812	2934	3060	3190	3323	3461	26	52	78	104	1·3603	3750	3903	4061	4224	4395	32	63	95	126
88	1·4572	4757	4950	5152	5363	5586	41	81	122	162	1·5821	6069	6332	6612	6912	7234	57	113	169	226
89	1·7581	7959	8373	8831	9342	9922	92	183	275	396	2·0592	1383	2352	3602	5363	8373	250	500	750	1000

FOR LONGITUDE BY CHRONOMETER.*

(V.) HALF LOG-HAVERSINES.

Deg	0′	5′	10′	15′	20′	25′	1′	2′	3′	4′	Deg	30′	35′	40′	45′	50′	55′	1′	2′	3′	4′
0°	0·000	1·862	2·163	2·339	2·464	2·561	35	70	106	141	0°	2·640	2·707	2·765	2·816	2·862	2·903	10	20	31	41
1	2·941	2·976	3·008	3·038	3·066	3·092	6	12	18	24	1	3·117	3·140	3·163	3·184	3·204	3·223	4	8	13	17
2	3·242	3·260	3·277	3·293	3·309	3·324	3	6	10	13	2	3·339	3·353	3·367	3·380	3·393	3·406	3	5	8	10
3	3·418	3·430	3·441	3·453	3·464	3·474	2	4	7	9	3	3·485	3·495	3·505	3·515	3·524	3·534	2	4	6	8
4	3·543	3·552	3·561	3·569	3·578	3·586	2	3	5	7	4	3·594	3·602	3·610	3·617	3·625	3·632	1	3	4	5
5	3·6397	6468	6539	6608	6677	6744	14	28	42	55	5	3·6810	6876	6940	7003	7066	7127	13	25	38	51
6	3·7188	7248	7307	7365	7422	7479	12	23	35	46	6	3·7535	7591	7645	7699	7752	7805	11	22	33	43
7	3·7857	7908	7959	8009	8059	8108	10	20	30	40	7	3·8156	8204	8251	8298	8345	8390	9	19	28	37
8	3·8436	8481	8525	8569	8613	8656	9	18	27	35	8	3·8699	8741	8783	8824	8865	8906	8	16	25	33
9	3·8946	8986	9026	9065	9104	9143	8	16	24	31	9	3·9181	9219	9256	9293	9330	9367	7	15	22	29
10	3·9402	9439	9475	9510	9545	9580	7	14	21	28	10	3·9614	9649	9682	9716	9750	9783	7	14	20	27
11	3·9816	9848	9881	9913	9945	9977	6	13	19	26	11	4·0008	0039	0070	0101	0132	0162	6	12	18	24
12	4·0192	0222	0252	0282	0311	0340	6	12	18	24	12	4·0369	0398	0426	0455	0483	0511	6	12	17	23
13	4·0539	0566	0594	0621	0648	0675	5	11	16	22	13	4·0702	0728	0755	0781	0807	0833	5	10	16	21
14	4·0859	0885	0910	0935	0961	0986	5	10	15	20	14	4·1011	1035	1059	1084	1109	1133	5	10	15	20
15	4·1157	1181	1205	1228	1252	1275	5	9	14	18	15	4·1299	1322	1345	1368	1390	1413	5	9	14	18
16	4·1436	1458	1480	1502	1525	1546	4	9	13	18	16	4·1568	1590	1612	1633	1655	1676	4	9	13	17
17	4·1697	1718	1739	1760	1781	1801	4	8	13	17	17	4·1822	1842	1863	1883	1903	1923	4	8	12	16
18	4·1943	1963	1983	2003	2022	2042	4	8	11	15	18	4·2061	2081	2100	2119	2138	2157	4	8	11	15
19	4·2176	2195	2214	2232	2251	2269	4	8	11	14	19	4·2288	2306	2324	2343	2361	2379	4	7	11	14

Deg	0′	10′	20′	30′	40′	50′	Deg	0′	10′	20′	30′	40′	50′	1′	2′	3′	4′	5′	6′	7′	8′	9′
20°	4·2397	2432	2468	2503	2538	2572	21	4·2606	2640	2673	2707	2740	2773	3	7	10	14	17	21	24	27	31
22	4·2806	2838	2870	2902	2934	2965	23	4·2997	3027	3058	3089	3119	3149	3	6	9	12	16	19	21	25	28
24	4·3179	3208	3238	3267	3296	3325	25	4·3353	3382	3410	3438	3466	3493	3	6	9	11	14	17	20	23	26
26	4·3521	3548	3575	3602	3629	3655	27	4·3682	3708	3734	3760	3786	3811	3	5	8	11	13	16	19	21	24
28	4·3837	3862	3887	3912	3937	3961	29	4·3986	4010	4034	4059	4083	4106	2	5	7	10	12	15	17	20	22
30	4·4130	4153	4177	4200	4223	4246	31	4·4269	4292	4314	4337	4359	4381	2	5	7	9	11	14	16	18	21
32	4·4403	4425	4447	4469	4490	4512	33	4·4533	4555	4576	4597	4618	4639	2	4	6	9	11	13	15	17	19
34	4·4659	4680	4700	4721	4741	4761	35	4·4781	4801	4821	4841	4861	4880	2	4	6	8	10	12	14	16	18
36	4·4900	4919	4939	4958	4977	4996	37	4·5015	5034	5052	5071	5090	5108	2	4	6	8	9	11	13	15	17
38	4·5126	5145	5163	5181	5199	5217	39	4·5235	5253	5270	5288	5306	5323	2	4	5	7	9	11	13	14	16
40	4·5341	5358	5375	5392	5409	5426	41	4·5443	5460	5477	5494	5510	5527	2	3	5	7	8	10	12	14	15
42	4·5543	5560	5576	5592	5609	5625	43	4·5641	5657	5673	5689	5704	5720	2	3	5	6	8	10	11	13	14
44	4·5736	5751	5767	5782	5798	5813	45	4·5828	5844	5859	5874	5889	5904	2	3	5	6	8	9	11	12	14
46	4·5919	5934	5948	5963	5978	5992	47	4·6007	6021	6036	6050	6065	6079	1	3	4	6	7	9	10	12	13
48	4·6093	6107	6121	6135	6149	6163	49	4·6177	6191	6205	6219	6232	6246	1	3	4	6	7	8	10	11	13
50	4·6259	6273	6286	6300	6313	6327	51	4·6340	6353	6366	6379	6392	6405	1	3	4	5	7	8	9	10	12
52	4·6418	6431	6444	6457	6470	6483	53	4·6495	6508	6521	6533	6546	6558	1	3	4	5	6	8	9	10	12
54	4·6570	6583	6595	6607	6620	6632	55	4·6644	6656	6668	6680	6692	6704	1	2	4	5	6	7	8	10	11
56	4·6716	6728	6740	6752	6763	6775	57	4·6787	6798	6810	6821	6833	6844	1	2	3	5	6	7	8	9	10
58	4·6856	6867	6878	6890	6901	6912	59	4·6923	6935	6946	6957	6968	6979	1	2	3	4	6	7	8	9	10
60	4·6990	7001	7012	7022	7033	7044	61	4·7055	7065	7076	7087	7097	7108	1	2	3	4	5	6	7	8	10
62	4·7118	7129	7139	7150	7160	7171	63	4·7181	7191	7201	7212	7222	7232	1	2	3	4	5	6	7	8	9
64	4·7242	7252	7262	7272	7282	7292	65	4·7302	7312	7322	7332	7342	7351	1	2	3	4	5	6	7	8	9
66	4·7361	7371	7380	7390	7400	7409	67	4·7419	7428	7438	7447	7457	7466	1	2	3	4	5	6	7	8	9
68	4·7476	7485	7494	7504	7513	7522	69	4·7531	7540	7550	7559	7568	7577	1	2	3	4	5	5	6	7	8
70	4·7586	7595	7604	7613	7622	7631	71	4·7640	7648	7657	7666	7675	7683	1	2	3	4	4	5	6	7	8
72	4·7692	7701	7710	7718	7727	7735	73	4·7744	7752	7761	7769	7778	7786	1	2	3	3	4	5	6	7	8
74	4·7795	7803	7811	7820	7828	7836	75	4·7844	7853	7861	7869	7877	7885	1	2	2	3	4	5	6	6	7
76	4·7893	7901	7910	7918	7926	7934	77	4·7942	7949	7957	7965	7973	7981	1	2	2	3	4	5	6	6	7
78	4·7989	7997	8004	8012	8020	8027	79	4·8035	8043	8050	8058	8066	8073	1	1	2	3	4	5	5	6	7

* *Vide* Examples page 43, worked by Inman's, Norie's, and The Secant Method.

(V.) HALF LOG-HAVERSINES.

Deg	0′	10′	20′	30′	40′	50′	Deg	0′	10′	20′	30′	40′	50′	1′	2′	3′	4′	5′	6′	7′	8′	9′
80°	4·8081	8088	8096	8103	8111	8118	81°	4·8125	8133	8140	8148	8155	8162	1	1	2	3	4	4	5	6	7
82	4·8169	8177	8184	8191	8198	8205	83	4·8213	8220	8227	8234	8241	8248	1	1	2	3	4	5	5	6	7
84	4·8255	8262	8269	8276	8283	8290	85	4·8297	8304	8311	8317	8324	8331	1	1	2	3	3	4	5	6	6
86	4·8338	8345	8351	8358	8365	8371	87	4·8378	8385	8391	8398	8405	8411	1	1	2	3	3	4	5	5	6
88	4·8418	8424	8431	8437	8444	8450	89	4·8457	8463	8469	8476	8482	8489	1	1	2	3	3	4	5	5	6
90	4·8495	8501	8507	8514	8520	8526	91	4·8532	8539	8545	8551	8557	8563	1	1	2	2	3	4	4	5	6
92	4·8569	8575	8581	8588	8594	8600	93	4·8606	8612	8618	8624	8629	8635	1	1	2	2	3	4	4	5	5
94	4·8641	8647	8653	8659	8665	8671	95	4·8676	8682	8688	8694	8699	8705	1	1	2	2	3	3	4	5	5
96	4·8711	8716	8722	8728	8733	8739	97	4·8745	8750	8756	8761	8767	8772	1	1	2	2	3	3	4	4	5
98	4·8778	8783	8789	8794	8800	8805	99	4·8810	8816	8821	8827	8832	8837	1	1	2	2	3	3	4	4	5
100	4·8843	8848	8853	8858	8864	8869	101	4·8874	8879	8884	8890	8895	8900	1	1	2	2	3	3	4	4	5
102	4·8905	8910	8915	8920	8925	8930	103	4·8935	8940	8945	8950	8955	8960	1	1	1	2	2	3	3	4	4
104	4·8965	8970	8975	8980	8985	8990	105	4·8995	9000	9004	9009	9014	9019	1	1	1	2	2	3	3	4	4
106	4·9023	9028	9033	9038	9042	9047	107	4·9052	9056	9061	9066	9070	9075	0	1	1	2	2	3	3	4	4
108	4·9080	9084	9089	9093	9098	9102	109	4·9107	9111	9116	9120	9125	9129	0	1	1	2	2	3	3	4	4
110	4·9134	9138	9142	9147	9151	9156	111	4·9160	9164	9169	9173	9177	9181	0	1	1	2	2	3	3	3	4
112	4·9186	9190	9194	9198	9203	9207	113	4·9211	9215	9219	9224	9228	9232	0	1	1	2	2	3	3	3	4
114	4·9236	9240	9244	9248	9252	9256	115	4·9260	9264	9268	9272	9276	9280	0	1	1	2	2	2	3	3	4
116	4·9284	9288	9292	9296	9300	9304	117	4·9308	9312	9315	9319	9323	9327	0	1	1	1	2	2	3	3	3
118	4·9331	9334	9338	9342	9346	9349	119	4·9353	9357	9361	9364	9368	9372	0	1	1	1	2	2	3	3	3
120	4·9375	9379	9383	9386	9390	9393	121	4·9397	9401	9404	9408	9411	9415	0	1	1	1	2	2	3	3	3
122	4·9418	9422	9425	9429	9432	9436	123	4·9439	9442	9446	9449	9453	9456	0	1	1	1	2	2	2	3	3
124	4·9459	9463	9466	9469	9473	9476	125	4·9479	9483	9486	9489	9492	9496	0	1	1	1	2	2	2	3	3
126	4·9499	9502	9505	9508	9512	9515	127	4·9518	9521	9524	9527	9530	9534	0	1	1	1	1	2	2	2	3
128	4·9537	9540	9543	9546	9549	9552	129	4·9555	9558	9561	9564	9567	9570	0	1	1	1	1	2	2	2	3
130	4·9573	9576	9579	9582	9584	9587	131	4·9590	9593	9596	9599	9602	9604	0	1	1	1	1	2	2	2	3
132	4·9607	9610	9613	9616	9618	9621	133	4·9624	9627	9629	9632	9635	9638	0	1	1	1	1	2	2	2	3
134	4·9640	9643	9646	9648	9651	9654	135	4·9656	9659	9661	9664	9667	9669	0	1	1	1	1	2	2	2	3
136	4·9672	9674	9677	9679	9682	9684	137	4·9687	9689	9692	9694	9697	9699	0	0	1	1	1	1	2	2	2
138	4·9702	9704	9706	9709	9711	9714	139	4·9716	9718	9721	9723	9725	9728	0	0	1	1	1	1	2	2	2
140	4·9730	9732	9734	9737	9739	9741	141	4·9743	9746	9748	9750	9752	9755	0	0	1	1	1	1	1	2	2
142	4·9757	9759	9761	9763	9765	9767	143	4·9770	9772	9774	9776	9778	9780	0	0	1	1	1	1	1	2	2
144	4·9782	9784	9786	9788	9790	9792	145	4·9794	9796	9798	9800	9802	9804	0	0	1	1	1	1	1	2	2
146	4·9806	9808	9810	9812	9814	9815	147	4·9817	9819	9821	9823	9825	9827	0	0	1	1	1	1	1	2	2
148	4·9828	9830	9832	9834	9836	9837	149	4·9839	9841	9843	9844	9846	9848	0	0	1	1	1	1	1	1	2
150	4·9849	9851	9853	9854	9856	9858	151	4·9859	9861	9863	9864	9866	9867	0	0	0	1	1	1	1	1	2
152	4·9869	9871	9872	9874	9875	9877	153	4·9878	9880	9881	9883	9884	9886	0	0	0	1	1	1	1	1	1
154	4·9887	9889	9890	9892	9893	9894	155	4·9896	9897	9899	9900	9901	9903	0	0	0	0	1	1	1	1	1
156	4·9904	9905	9907	9908	9909	9911	157	4·9912	9913	9914	9916	9917	9918	0	0	0	0	1	1	1	1	1
158	4·9919	9921	9922	9923	9924	9925	159	4·9927	9928	9929	9930	9931	9932	0	0	0	0	1	1	1	1	1
160	4·9934	9935	9936	9937	9938	9939	161	4·9940	9941	9942	9943	9944	9945	0	0	0	0	1	1	1	1	1
162	4·9946	9947	9948	9949	9950	9951	163	4·9952	9953	9954	9955	9956	9957	0	0	0	0	0	1	1	1	1
164	4·9958	9958	9959	9960	9961	9962	165	4·9963	9964	9964	9965	9966	9967	0	0	0	0	0	0	1	1	1
166	4·9968	9968	9969	9970	9971	9971	167	4·9972	9973	9973	9974	9975	9975	0	0	0	0	0	0	0	0	1
168	4·9976	9977	9977	9978	9979	9979	169	4·9980	9981	9981	9982	9982	9983	0	0	0	0	0	0	0	0	1
170	4·9983	9984	9985	9985	9986	9986	171	4·9987	9987	9988	9988	9989	9989	0	0	0	0	0	0	0	0	1
172	4·9989	9990	9990	9991	9991	9991	173	4·9992	9992	9993	9993	9993	9994	0	0	0	0	0	0	0	0	1
174	4·9994	9994	9995	9995	9995	9996	175	4·9996	9996	9996	9997	9997	9997	0	0	0	0	0	0	0	0	0
176	4·9997	9998	9998	9998	9998	9998	177	4·9999	9999	9999	9999	9999	9999	0	0	0	0	0	0	0	0	0
178	4·9999	9999	9999	9999	9999	9999	179	4·9999	9999	9999	9999	9999	5·0000	0	0	0	0	0	0	0	0	0

(VI.) LOG HAVERSINES OF THE HOUR-ANGLE.

P.M., or West of Meridian. — Parts for Seconds.

P.M.	M 0	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	S 1	S 5	S 10	S 15	S 20	S 25	S 30	S 35	S 40	S 45	S 50	S 55	A.M.
H M																							M H
0 ·0	0·000	4·678	5·280	5·632	5·882	6·075	6·234	6·368	6·484	6·586	...	...	...	...	...	...	...	...	...	...	...	...	50
10	6·678	6·760	6·836	6·905	6·970	7·030	7·086	7·138	7·188	7·235	...	...	...	...	...	...	...	...	...	...	...	...	40
20	7·279	7·322	7·362	7·401	7·438	7·473	7·507	7·540	7·571	7·602	·6	3	6	9	12	14	17	20	23	26	29	31	30
30	7·631	7·660	7·687	7·714	7·740	7·765	7·789	7·813	7·836	7·859	·4	2	4	6	8	11	13	15	17	19	21	23	20
40	7·881	7·902	7·923	7·943	7·963	7·983	8·002	8·020	8·038	8·056	·4	2	3	5	7	8	10	12	13	15	17	18	10
50	8·074	8·091	8·108	8·124	8·140	8·156	8·172	8·187	8·202	8·217	·3	1	3	4	5	7	8	9	11	12	13	15	0 ·11
	8.																						
1 ·0	2314	2457	2597	2735	2871	3005	3137	3266	3394	3520	2·0	11	22	33	45	56	67	78	89	100	112	123	50
10	3644	3766	3887	4005	4123	4238	4352	4465	4576	4685	2·0	10	19	29	38	48	58	67	77	86	96	105	40
20	4793	4900	5006	5110	5213	5314	5415	5514	5612	5709	1·7	8	17	25	34	42	50	59	67	76	84	93	30
30	5805	5899	5993	6086	6177	6268	6358	6446	6534	6621	1·5	7	15	22	30	37	45	52	60	67	75	82	20
40	6707	6792	6876	6959	7042	7123	7204	7284	7364	7442	1·4	7	13	20	27	34	40	47	54	61	67	74	10
50	7520	7597	7673	7749	7824	7898	7972	8045	8117	8189	1·2	6	12	18	25	31	37	43	49	55	62	68	0 ·10
	8.																						
2 ·0	8260	8330	8400	8469	8538	8606	8673	8740	8807	8873	1·1	6	11	17	23	28	34	40	45	51	57	62	50
10	8938	9003	9067	9131	9194	9256	9319	9380	9442	9503	1·0	5	10	16	21	26	31	36	41	46	52	57	40
20	9563	9623	9682	9741	9800	9858	9915	9973	9·0030	0086	1·0	5	10	14	19	24	29	34	39	43	48	53	30
30	0142	0198	0253	0308	0362	0416	0470	0523	0576	0629	·9	4	9	13	18	22	27	31	36	40	45	49	20
40	0681	0733	0784	0836	0887	0937	0987	1037	1087	1136	·8	4	8	12	17	21	25	29	33	37	42	46	10
50	1185	1233	1282	1329	1377	1424	1472	1518	1565	1611	·8	4	8	12	16	20	23	27	31	35	39	43	0 ·9
	9.																						
3 ·0	1657	1702	1748	1793	1838	1882	1926	1970	2014	2057	·7	4	7	11	15	18	22	26	29	33	37	40	50
10	2101	2144	2186	2229	2271	2313	2355	2396	2437	2478	·7	3	7	10	14	17	21	24	28	31	35	38	40
20	2519	2559	2600	2640	2680	2719	2759	2798	2837	2876	·6	3	6	10	13	16	19	23	26	29	32	36	30
30	2914	2952	2991	3028	3066	3104	3141	3178	3215	3252	·6	3	6	9	12	15	18	22	25	28	31	34	20
40	3288	3324	3361	3396	3432	3468	3503	3538	3573	3608	·6	3	6	9	12	15	18	21	24	27	29	32	10
50	3643	3677	3711	3746	3779	3813	3847	3880	3913	3946	·6	3	6	8	11	14	17	20	23	25	28	31	0 ·8
	9.																						
4 ·0	3979	4012	4045	4077	4109	4141	4173	4205	4237	4268	·5	3	5	8	11	13	16	19	21	24	27	29	50
10	4300	4331	4362	4393	4423	4454	4484	4514	4545	4575	·5	3	5	8	10	13	15	18	21	23	25	28	40
20	4604	4634	4664	4693	4722	4751	4780	4809	4838	4866	·5	2	5	7	10	12	14	17	19	22	24	27	30
30	4895	4923	4951	4979	5007	5035	5063	5090	5117	5145	·5	2	5	7	9	12	14	16	19	21	23	26	20
40	5172	5199	5226	5252	5279	5306	5332	5358	5384	5410	·4	2	4	7	9	11	13	16	18	20	22	24	10
50	5436	5462	5488	5513	5539	5564	5589	5614	5639	5664	·4	2	4	6	8	10	12	15	17	19	21	23	0 ·7
	9.																						
5 ·0	5689	5714	5738	5763	5787	5811	5835	5859	5883	5907	·4	2	4	6	8	10	12	14	16	19	20	22	50
10	5930	5954	5977	6001	6024	6047	6070	6093	6116	6139	·4	2	4	6	8	10	11	13	15	17	19	21	40
20	6161	6184	6206	6229	6251	6273	6295	6317	6339	6361	·4	2	4	5	7	9	11	13	15	16	18	20	30
30	6382	6404	6425	6447	6468	6489	6510	6531	6552	6573	·3	2	3	5	7	9	10	12	14	16	17	19	20
40	6594	6614	6635	6655	6676	6696	6716	6736	6756	6776	·3	2	3	5	7	8	10	12	13	15	17	19	10
50	6796	6816	6835	6855	6874	6894	6913	6932	6952	6971	·3	2	3	5	6	8	10	11	13	15	16	18	0 ·6
	9.																						
6 ·0	6990	7009	7027	7046	7065	7083	7102	7120	7139	7157	·3	2	3	4	6	7	9	10	12	14	15	17	50
10	7175	7193	7211	7229	7247	7265	7283	7300	7318	7335	·3	2	3	4	6	7	9	10	12	14	15	17	40
20	7353	7370	7387	7404	7421	7438	7455	7472	7489	7506	·3	1	3	4	6	7	8	10	11	13	14	16	30
30	7523	7539	7556	7572	7588	7605	7621	7637	7653	7669	·3	1	3	4	6	7	8	10	11	13	14	16	20
40	7685	7701	7717	7732	7748	7764	7779	7795	7810	7825	·3	1	3	4	5	7	8	9	11	12	14	15	10
50	7841	7856	7871	7886	7901	7916	7931	7945	7960	7975	·2	1	2	4	5	6	7	9	10	11	12	14	0 ·5
	9.																						
7 ·0	7989	8004	8018	8033	8047	8061	8075	8090	8104	8118	·2	1	2	4	5	6	7	8	9	10	12	13	50
10	8131	8145	8159	8173	8187	8200	8214	8227	8241	8254	·2	1	2	4	5	6	7	8	9	10	12	13	40
20	8267	8281	8294	8307	8320	8333	8346	8359	8371	8384	·2	1	2	3	4	5	6	8	9	10	11	12	30
30	8397	8410	8422	8435	8447	8459	8472	8484	8496	8508	·2	1	2	3	4	5	6	8	9	10	11	12	20
40	8521	8533	8545	8557	8568	8580	8592	8604	8615	8627	·2	1	2	3	4	5	6	7	8	9	10	11	10
50	8638	8650	8661	8673	8684	8695	8706	8718	8729	8740	·2	1	2	3	4	5	5	6	7	8	9	10	0 ·4
P.M.	M 10	M 9	M 8	M 7	M 6	M 5	M 4	M 3	M 2	M 1	S 1	S 5	S 10	S 15	S 20	S 25	S 30	S 35	S 40	S 45	S 50	S 55	A.M.

A.M. or East of Meridian. — Parts for Seconds.

For **A.M. Time** look for the log. next **greater**, and for **P.M.** that next **less**; the difference in either case gives the seconds. Also p.m. time subtracted from **12 Hours** gives a.m. time.

(VII.) LOG-COSINES.

														SUBTRACT PARTS FOR MINUTES.								
	0′	10′	20′	30′	40′	50′		0′	10′	20′	30′	40′	50′	1′	2′	3′	4′	5′	6′	7′	8′	9′
°							°										S	U	B			
0	5·0000	0000	0000	0000	0000	4·9999	1	4·9999	9999	9999	9999	9998	9998	0	0	0	0	0	0	0	0	0
2	4·9997	9996	9996	9995	9995	9995	3	4·9994	9993	9993	9992	9991	9990	0	0	0	0	0	1	1	1	1
4	4·9989	9989	9988	9987	9986	9985	5	4·9983	9982	9981	9980	9979	9977	0	0	0	0	0	1	1	1	1
6	4·9976	9975	9973	9972	9971	9969	7	4·9968	9966	9964	9963	9961	9959	0	0	0	1	1	1	1	2	2
8	4·9958	9956	9954	9952	9950	9948	9	4·9946	9944	9942	9940	9938	9936	0	0	0	1	1	1	1	2	2
10	4·9934	9931	9929	9927	9924	9922	11	4·9919	9917	9914	9912	9909	9907	0	0	1	1	1	1	2	2	2
12	4·9904	9901	9899	9896	9893	9890	13	4·9887	9884	9881	9878	9875	9872	0	1	1	1	1	2	2	2	3
14	4·9869	9866	9863	9859	9856	9853	15	4·9849	9846	9843	9839	9836	9832	0	1	1	1	2	2	2	2	3
16	4·9828	9825	9821	9817	9814	9810	17	4·9806	9802	9798	9794	9790	9786	0	1	1	1	2	2	3	3	3
18	4·9782	9778	9774	9770	9765	9761	19	4·9757	9752	9748	9743	9739	9734	0	1	1	2	2	3	3	3	4
20	4·9730	9725	9721	9716	9711	9706	21	4·9702	9697	9692	9687	9682	9677	0	1	1	2	2	3	3	4	4
22	4·9672	9667	9661	9656	9651	9646	23	4·9640	9635	9629	9624	9618	9613	0	1	2	2	3	3	4	4	5
24	4·9607	9602	9596	9590	9584	9579	25	4·9573	9567	9561	9555	9549	9543	1	1	2	2	3	3	4	5	5
26	4·9537	9530	9524	9518	9512	9505	27	4·9499	9492	9486	9479	9473	9466	1	1	2	2	3	4	4	5	6
28	4·9459	9453	9446	9439	9432	9425	29	4·9418	9411	9404	9397	9390	9383	1	1	2	3	3	4	5	6	6
30	4·9375	9368	9361	9353	9346	9338	31	4·9331	9323	9315	9308	9300	9292	1	1	2	3	4	4	5	6	7
32	4·9284	9276	9268	9260	9252	9244	33	4·9236	9228	9219	9211	9203	9194	1	2	2	3	4	5	6	6	7
34	4·9186	9177	9169	9160	9151	9142	35	4·9134	9125	9116	9107	9098	9089	1	2	3	4	4	5	6	7	8
36	4·9080	9070	9061	9052	9042	9033	37	4·9023	9014	9004	8995	8985	8975	1	2	3	4	5	6	7	8	9
38	4·8965	8955	8945	8935	8925	8915	39	4·8905	8895	8884	8874	8864	8853	1	2	3	4	5	6	7	8	9
40	4·8843	8832	8821	8810	8800	8789	41	4·8778	8767	8756	8745	8733	8722	1	2	3	4	5	7	8	9	10
42	4·8711	8699	8688	8676	8665	8653	43	4·8641	8629	8618	8606	8594	8581	1	2	3	5	6	7	8	9	10
44	4·8569	8557	8545	8532	8520	8507	45	4·8495	8482	8469	8457	8444	8431	1	2	4	5	6	7	9	10	11
46	4·8418	8404	8391	8378	8365	8351	47	4·8338	8324	8311	8297	8283	8269	1	3	4	5	7	8	9	11	12
48	4·8255	8241	8227	8213	8198	8184	49	4·8169	8155	8140	8125	8111	8096	1	3	4	6	7	9	10	12	13
50	4·8081	8066	8050	8035	8020	8004	51	4·7989	7973	7957	7941	7926	7910	2	3	5	6	8	9	11	12	14
52	4·7893	7877	7861	7844	7828	7811	53	4·7795	7778	7761	7744	7727	7710	2	3	5	7	8	10	12	13	15
54	4·7692	7675	7657	7640	7622	7604	55	4·7586	7568	7550	7531	7513	7494	2	4	5	7	9	11	13	14	16
56	4·7476	7457	7438	7419	7400	7380	57	4·7361	7342	7322	7302	7282	7262	2	4	6	8	10	12	14	16	18
58	4·7242	7222	7201	7181	7160	7139	59	4·7118	7097	7076	7055	7033	7012	2	4	6	8	10	13	15	17	19
60	4·6990	6968	6946	6923	6901	6878	61	4·6856	6833	6810	6787	6763	6740	2	4	7	9	11	14	16	18	20
62	4·6716	6692	6668	6644	6620	6595	63	4·6570	6546	6521	6495	6470	6444	2	5	7	10	12	15	17	20	22
64	4·6418	6392	6366	6340	6313	6286	65	4·6259	6232	6205	6177	6149	6121	3	5	8	11	13	16	19	22	24
66	4·6093	6065	6036	6007	5978	5948	67	4·5919	5889	5859	5828	5798	5767	3	6	9	12	15	18	21	24	27
68	4·5736	5704	5673	5641	5609	5576	69	4·5543	5510	5477	5443	5409	5375	3	7	10	13	16	20	23	26	30

	0′	5′	10′	15′	20′	25′	1′	2′	3′	4′	30′	35′	40′	45′	50′	55′	1′	2′	3′	4′
°																				
70	4·5341	5323	5306	5288	5270	5253	3	7	10	14	5235	5217	5199	5181	5163	5145	4	7	11	14
71	4·5126	5108	5090	5071	5052	5034	4	7	11	15	5015	4996	4977	4958	4939	4919	4	8	11	15
72	4·4900	4880	4861	4841	4821	4801	4	8	11	16	4781	4761	4741	4721	4700	4680	4	8	12	16
73	4·4659	4639	4618	4597	4576	4555	4	8	12	17	4533	4512	4491	4469	4447	4425	4	9	13	17
74	4·4403	4381	4359	4337	4314	4292	4	9	13	18	4269	4246	4223	4200	4177	4153	5	9	14	19
75	4·4130	4106	4083	4059	4035	4010	5	10	14	19	3986	3961	3937	3912	3887	3862	5	10	15	20
76	4·3837	3811	3786	3760	3734	3708	5	10	15	20	3682	3655	3629	3602	3575	3548	5	11	16	21
77	4·3521	3493	3466	3438	3410	3382	6	11	16	22	3353	3325	3296	3267	3238	3208	6	12	17	23
78	4·3179	3149	3119	3089	3058	3027	6	12	18	24	2996	2965	2934	2902	2870	2838	6	13	19	25
79	4·2806	2773	2740	2707	2674	2640	7	13	20	26	2606	2572	2538	2503	2468	2432	7	14	21	28
80	4·2397	2361	2324	2288	2251	2214	7	15	22	29	2176	2138	2100	2061	2022	1983	8	15	23	31
81	4·1943	1903	1863	1822	1781	1739	8	16	24	33	1697	1655	1612	1568	1525	1480	9	17	26	35
82	4·1436	1390	1345	1299	1252	1205	9	18	28	37	1157	1109	1060	1011	0961	0910	10	20	30	39
83	4·0859	0807	0755	0702	0648	0594	11	21	32	43	0539	0483	0426	0369	0311	0252	11	23	34	46
84	4·0192	0132	0070	0008	3·9945	3·9881	12	25	37	50	3·9816	9750	9682	9614	9545	9475	14	27	41	55
85	3·9403	9330	9256	9181	9104	9026	15	30	45	60	8946	8865	8783	8699	8613	8525	17	34	50	67
86	3·8436	8345	8251	8156	8059	7959	19	38	59	76	7857	7752	7645	7535	7423	7307	22	44	66	88
87	3·7188	7066	6940	6810	6677	6539	26	52	78	104	6397	6250	6097	5939	5776	5605	32	63	95	126
88	3·5428	5243	5050	4848	4637	4414	41	81	122	162	4179	3931	3668	3388	3088	2766	57	113	169	226
89	3·2419	2041	1627	1169	0658	0078	92	183	295	396	2·9408	8617	7648	6398	4637	1627	250	500	750	1000

TRAVERSE TABLE.

(VIII.) DIFF. LAT. AND DEP. FOR DIST. 1′.*

Co.	0°		1°		2°		3°		4°		5°		6°		7°		8°		9°		Co.
DEG.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	D.lat	Dep.	DEG.
0°	1·00	·00	1·00	·02	1·00	·03	1·00	·05	1·00	·07	1·00	·09	·99	·10	·99	·12	·99	·14	·99	·16	0°
10	·98	·17	·98	·19	·98	·21	·97	·22	·97	·24	·97	·26	·96	·28	·96	·29	·95	·31	·95	·33	10
20	·94	·34	·93	·36	·93	·37	·92	·39	·91	·41	·91	·42	·90	·44	·89	·45	·88	·47	·87	·48	20
30	·87	·50	·86	·51	·85	·53	·84	·54	·83	·56	·82	·57	·81	·59	·80	·60	·79	·62	·78	·63	30
40	·77	·64	·75	·66	·74	·67	·73	·68	·72	·69	·71	·71	·69	·72	·68	·73	·67	·74	·66	·75	40
50	·64	·77	·63	·78	·62	·79	·60	·80	·59	·81	·57	·82	·56	·83	·54	·84	·53	·85	·51	·86	50
60	·50	·87	·48	·87	·47	·88	·45	·89	·44	·90	·42	·91	·41	·91	·39	·92	·37	·93	·36	·93	60
70	·34	·94	·33	·95	·31	·95	·29	·96	·28	·96	·26	·97	·24	·97	·22	·97	·21	·98	·19	·98	70
80	·17	·98	·16	·99	·14	·99	·12	·99	·10	·99	·09	1·00	·07	1·00	·05	1·00	·03	1·00	·02	1·00	80

To Convert Dep. into D.long. Take the lat. as Course and find D.lat. Then the dep. ÷ this D.lat. = D.long.
Ex.: Lat. 50° and Dep. 53′. Here Co. 50° gives D. Lat. ·64. And 53 ÷ ·64 = 83′ D.long. and so on.

(IX.) CORR. FOR SUN'S OBS. ALT. +

HEIGHT IN FEET.

ALT.	5	10	15	20	25	30	35	40	45	50	55	60
6°	5	5	4	4	3	3	2	2	1	1	1	0
7	7	6	5	4	4	3	3	3	2	2	1	1
8	7	6	6	5	5	4	4	3	3	3	3	2
10	9	8	7	6	6	5	5	5	4	4	4	4
15	10	9	9	8	8	7	7	6	6	6	5	5
20	11	10	10	9	9	8	8	7	7	7	6	6
25	12	11	10	10	9	9	8	8	7	7	7	6
30	12	11	11	10	10	9	9	8	8	8	7	7
35	13	12	11	10	10	9	9	9	8	8	7	7
40	13	12	11	11	10	10	9	8	8	8	7	7
45	13	12	11	11	10	10	10	9	9	9	8	8
50	13	12	11	11	10	10	10	9	9	9	9	8
60	13	12	12	11	10	10	10	9	9	9	8	8
70	13	13	12	11	11	10	10	9	9	9	8	8
80	14	13	12	11	11	10	10	10	9	9	8	8

CORR. FOR STAR'S OBS. ALT. −

HEIGHT IN FEET.

ALT.	5	10	15	20	25	30	35	40	45	50	55	60
6°	10	11	12	13	13	14	14	15	15	15	15	16
7	9	10	11	12	12	13	13	14	14	14	15	15
8	9	10	10	11	11	12	12	13	13	13	14	14
10	7	8	9	10	10	11	11	11	12	12	12	13
15	6	7	7	8	8	9	9	10	10	10	11	11
20	5	5	6	7	7	8	8	9	9	9	10	10
25	4	5	6	6	7	7	8	8	9	9	9	10
30	4	5	5	6	6	7	7	8	8	9	9	9
35	3	4	5	6	6	7	7	8	8	8	9	9
40	3	4	5	5	6	6	7	7	8	8	8	9
45	3	4	5	5	6	6	7	7	7	8	8	8
50	3	4	5	5	6	6	7	7	7	8	8	8
60	3	4	4	5	5	6	6	7	7	7	8	8
70	2	3	4	5	5	6	6	6	7	7	8	8
80	2	3	4	4	5	5	6	6	7	7	7	8

(X.) FOR CONVERTING ARC INTO TIME, AND TIME INTO ARC.

DEG	° ′ 0	° ′ 1	° ′ 2	° ′ 3	° ′ 4	° ′ 5	° ′ 6	° ′ 7	° ′ 8	° ′ 9	DEG
° ′	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	H. M. M. S.	° ′
0	0 0	0 4	0 8	0 12	0 16	0 20	0 24	0 28	0 32	0 36	0
10	0 40	0 44	0 48	0 52	0 56	1 0	1 4	1 8	1 12	1 16	10
20	1 20	1 24	1 28	1 32	1 36	1 40	1 44	1 48	1 52	1 56	20
30	2 0	2 4	2 8	2 12	2 16	2 20	2 24	2 28	2 32	2 36	30
40	2 40	2 44	2 48	2 52	2 56	3 0	3 4	3 8	3 12	3 16	40
50	3 20	3 24	3 28	3 32	3 36	3 40	3 44	3 48	3 52	3 56	50
60	4 0	4 4	4 8	4 12	4 16	4 20	4 24	4 28	4 32	4 36	60
70	4 40	4 44	4 48	4 52	4 56	5 0	5 4	5 8	5 12	5 16	70
80	5 20	5 24	5 28	5 32	5 36	5 40	5 44	5 48	5 52	5 56	80

If the degrees exceed 90°, find the time for those in excess and add 6 hours. Also add 1 sec. of time for each ¼′.

* Diff. Lat. and Dep. for distances 1′ to 31′ may be found without multiplication by Tab. IIa. in the same way as in finding the Longitude Correction, by entering with Diff. Lat. and Dep. for 1′ at the side and the Dist. at the top.

(XI.)	GREENWICH TIME FROM NOON.											MINUTES.				
H.D.	H 1	H 2	H 3	H 4	H 5	H 6	H 7	H 8	H 9	H 10	H 11	H 12	M 10	M 20	M 30	M 40	M 50
″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	″	″	″	″	″
1	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	0·10	0·11	0·12	0	0	1	1	1
2	0·2	0·4	0·6	0·8	0·10	0·12	0·14	0·16	0·18	0·20	0·22	0·24	0	1	1	1	1
3	0·3	0·6	0·9	0·12	0·15	0·18	0·21	0·24	0·27	0·30	0·33	0·36	0	1	1	2	2
4	0·4	0·8	0·12	0·16	0·20	0·24	0·28	0·32	0·36	0·40	0·44	0·48	1	1	2	3	3
5	0·5	0·10	0·15	0·20	0·25	0·30	0·35	0·40	0·45	0·50	0·55	1·00	1	2	2	3	4
6	0·6	0·12	0·18	0·24	0·30	0·36	0·42	0·48	0·54	1·0	1·6	1·12	1	2	3	4	5
7	0·7	0·14	0·21	0·28	0·35	0·42	0·49	0·56	1·3	1·10	1·17	1·24	1	2	3	4	5
8	0·8	0·16	0·24	0·32	0·40	0·48	0·56	1·4	1·12	1·20	1·28	1·36	1	3	4	5	6
9	0·9	0·18	0·27	0·36	0·45	0·54	1·3	1·12	1·21	1·30	1·39	1·48	1	3	4	6	7
10	0·10	0·20	0·30	0·40	0·50	1·0	1·10	1·20	1·30	1·40	1·50	2·0	2	3	5	7	8
11	0·11	0·22	0·33	0·44	0·55	1·6	1 17	1·28	1·39	1·50	2·1	2·12	2	4	6	8	9
12	0·12	0·24	0·36	0·48	1·0	1·12	1·24	1·36	1·48	2·0	2·12	2·24	2	4	6	8	10
13	0·13	0·26	0·39	0·52	1·5	1·18	1·31	1·44	1·57	2·10	2·23	2·36	2	4	6	8	10
14	0·14	0·28	0·42	0·56	1·10	1·24	1·38	1·52	2·6	2·20	2·34	2·48	2	5	7	9	11
15	0·15	0·30	0·45	1·0	1·15	1·30	1·45	2·0	2·15	2·30	2·45	3·0	2	5	7	10	12
16	0·16	0·32	0·48	1·4	1·20	1·36	1·52	2·8	2·24	2·40	2·56	3·12	3	5	8	11	13
17	0·17	0·34	0·51	1·8	1·25	1·42	1·59	2·16	2·33	2·50	3·7	3·24	3	6	8	11	14
18	0·18	0·36	0·54	1·12	1·30	1·48	2·6	2·24	2·42	3·0	3·18	3·36	3	6	9	12	15
19	0·19	0·38	0·57	1·16	1·35	1·54	2·13	2·32	2·51	3·10	3·29	3·48	3	6	9	12	15
20	0·20	0·40	1·0	1·20	1·40	2·0	2·20	2·40	3·0	3·20	3·40	4·0	3	7	10	13	16
21	0·21	0·42	1·3	1·24	1·45	2·6	2·27	2·48	3·9	3·30	3·51	4·12	3	7	10	14	16
22	0·22	0·44	1·6	1·28	1·50	2·12	2·34	2·56	3·18	3·40	4·2	4·24	4	7	11	15	18
23	0·23	0·46	1·9	1·32	1·55	2·18	2·41	3·4	3·27	3·50	4·13	4·36	4	8	11	15	19
24	0·24	0·48	1·12	1·36	2·0	2·24	2·48	3·12	3·36	4·0	4·24	4·48	4	8	12	16	20
25	0·25	0·50	1·15	1·40	2·5	2·30	2·55	3·20	3·45	4·10	4·35	5·0	4	8	12	16	20
26	0·26	0·52	1·18	1·44	2·10	2·36	3·2	3·28	3·54	4·20	4·46	5·12	4	9	13	17	21
27	0·27	0·54	1·21	1·48	2·15	2·42	3·9	3·36	4·3	4·30	4·57	5·24	4	9	13	18	22
28	0·28	0·56	1·24	1·52	2·20	2·48	3·16	3·44	4·12	4·40	5·8	5·36	5	9	14	19	23
29	0·29	0·58	1·27	1·56	2·25	2·54	3·23	3·52	4·21	4·50	5·19	5·48	5	10	14	19	24
30	0·30	1·0	1·30	2·0	2·30	3·0	3·30	4·0	4·30	5·0	5·30	6·0	5	10	15	20	25
31	0·31	1·2	1·33	2·4	2·35	3·6	3·37	4·8	4·39	5·10	5·41	6·12	5	10	15	21	26
32	0·32	1·4	1·36	2·8	2·40	3·12	3·44	4·16	4·48	5·20	5·52	6·24	5	11	16	21	27
33	0·33	1·6	1·39	2·12	2·45	3·18	3·51	4·24	4·57	5·30	6·3	6·36	5	11	16	22	27
34	0·34	1·8	1·42	2·16	2·50	3·24	3·58	4·32	5·6	5·40	6·14	6·48	6	11	17	23	28
35	0·35	1·10	1·45	2·20	2·55	3·30	4·5	4·40	5·15	5·50	6·25	7·0	6	12	17	23	29
36	0·36	1·12	1·48	2·24	3·0	3·36	4·12	4·48	5·24	6·0	6·36	7·12	6	12	18	24	30
37	0·37	1·14	1·51	2·28	3·5	3·42	4·19	4·56	5·33	6·10	6·47	7·24	6	12	18	25	31
38	0·38	1·16	1·54	2·32	3·10	3·48	4·26	5·4	5·42	6·20	6·58	7·36	6	13	19	25	32
39	0·39	1·18	1·57	2·36	3·15	3·54	4·33	5·12	5·51	6·30	7·9	7·48	6	13	19	26	32
40	0·40	1·20	2·0	2·40	3·20	4·0	4.40	5·20	6·0	6·40	7·20	8·0	7	13	20	27	33
41	0·41	1·22	2·3	2·44	3·25	4·6	4·47	5·28	6·9	6·50	7·31	8·12	7	14	20	27	34
42	0·42	1·24	2·6	2·48	3·30	4·12	4·54	5·36	6·18	7·0	7·42	8·24	7	14	21	28	35
43	0·43	1·26	2·9	2·52	3·35	4·18	5·1	5·44	6·27	7·10	7·53	8·36	7	14	21	29	36
44	0·44	1·28	2·12	2·56	3·40	4·24	5·8	5·52	6·36	7·20	8·4	8·48	7	15	22	29	37
45	0·45	1·30	2·15	3·0	3·45	4·30	5·15	6·0	6·45	7·30	8·15	9·0	7	15	22	30	37
46	0·46	1·32	2·18	3·4	3·50	4·36	5·22	6·8	6·54	7·40	8·26	9·12	8	15	23	31	38
47	0·47	1·34	2·21	3·8	3·55	4·42	5·29	6·16	7·3	7·50	8·37	9·24	8	16	23	31	39
48	0·48	1·36	2·24	3·12	4·0	4·48	5·36	6·24	7·12	8·0	8·48	9·36	8	16	24	32	40
49	0·49	1·38	2·27	3·16	4·5	4·54	5·43	6·32	7·21	8·10	8·59	9·48	8	16	24	33	41
50	0·50	1·40	2·30	3·20	4·10	5·0	5·50	6·40	7·30	8·20	9·10	10·0	8	17	25	33	42
51	0·51	1·42	2·33	3·24	4·15	5·6	5·57	6·48	7·39	8·30	9·21	10·12	8	17	25	34	42
52	0·52	1·44	2·36	3·28	4·20	5·12	6·4	6·56	7·48	8·40	9·32	10·24	9	17	26	35	43
53	0·53	1·46	2·39	3·32	4·25	5·18	6·11	7·4	7·57	8·50	9·43	10·36	9	18	26	35	44
54	0·54	1·48	2·42	3·36	4·30	5·24	6·18	7·12	8·6	9·0	9·54	10·48	9	18	27	36	45
55	0·55	1·50	2·45	3·40	4·35	5·30	6·25	7·20	8·15	9·10	10·5	11·0	9	18	27	37	46
56	0·56	1·52	2·48	3·44	4·40	5·36	6·32	7·28	8·24	9·20	10·16	11·12	9	19	28	37	47
57	0·57	1·54	2·51	3·48	4·45	5·42	6·39	7·36	8·33	9·30	10·27	11·24	9	19	28	38	47
58	0·58	1·56	2·54	3·52	4·50	5·48	6·46	7·44	8·42	9·40	10·38	11·36	10	19	29	39	48
59	0·59	1·58	2·57	3·56	4·55	5·54	6·53	7·52	8·51	9·50	10·49	11·48	10	20	29	39	49
60	0·60	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	10·0	11·0	12·0	10	20	30	40	50

EXAMPLES

To show the reliability of the foregoing Abbreviated Tables: *vide* also Notes next page.

Finding the Time.

Ex. I. By Inman's Method.

(Lat. and Dec. of same name.)

Lat.	40° 23′ N.	·1182 ... log. sec.	
Dec.	10 7 N.	·0068 ... ,, ,,	
Diff.	30 16		
Z.D.	60 42		
Sum	90 58	4·8531 ... ½-log. Hav.	
Diff.	30 26	4·4191 ... ,, ,,	
Log Hav.		9·3972	
		H. M. S.	
H.A. ...		3 59 47	

Ex. I. By Norie, &c., modified.

(Lat. and Dec. of same name.)

Lat.	40° 23′	·1182 ... log. sec.
P.D.	79 53	·0068 ... ,, ,, (dec.)
Alt.	29 18	
Sum	149 34	
½-sum	74 47	4·4191 ... log. cosine
*Remr.	44 31	4·8531 ... ,, ,,
Log. Hav.		9·3972
		H. M. S.
H.A. ...		3 59 47

Ex. II. By Inman.

(Lat. and Dec. of contrary names.)

Lat.	38° 30′ N.	·1065 ... log. sec.
Dec.	5 15 S.	·0018 ... ,, ,,
Sum	43 45	
Z.D.	70 21	
Sum	114 6	4·9238 ... ½-log. Hav.
Diff.	26 36	4·3618 ... ,, ,,
Log. Hav.		9·3939
		H. M. S.
H.A. ...		3 58 47

Ex. II. By Norie, modified.

(Lat. and Dec. of contrary names.)

Lat.	38° 30′	·1065 ... log. sec.
P.D.	95 15	·0018 ... ,, ,, (dec.)
Alt.	19 39	
Sum	153 24	
½-sum	76 42	4·3618 ... log. cos.
*Remr.	32 57	4·9238 ... log. cos.
Log. Hav.		9·3939
		H. M. S.
H.A. ...		3 58 47

* In the examples on the right-hand side of the page, the remainder is found by subtracting the half sum from the Altitude increased by 90°. Thus in Example I. it is subtracted from 119° 18′, and in II. from 109° 39′. To do this we proceed in the usual way till the last figure is reached, then borrow 9 instead of 10.

The Secant Method.

Add together the Log. Secants of the Latitude and *declination* (A)
And those of the half sum and remainder ... ... (B)

Then 10 + Log. A. − Log B. = Log. Hav. H.A.

EXAMPLES.

Ex. I. (above).

40° 23′	·1182 ... log. sec.
79 53	·0068 ... ,, ,, (dec.)
29 18	·1250 (A.)
149 34	
74 47	·5809 ... log. sec.
44 31	·1469 ... ,, ,,
	·7278 (B.)
Log. Hav.	9·3972 (A.—B.)
	H. M. S.
H.A. ...	3 59 47

Ex. II. (above).

38° 30′	·1065 ... log. sec.
95 15	·0018 ... ,, ,, (dec.)
19 39	·1083 (A.)
153 24	
76 42	·6382 ... log. sec.
32 57	·0762 ... ,, ,,
	·7144 (B.)
Log. Hav.	9·3939 (A.—B.)
	H. M. S.
H.A. ...	3 58 47

These results are identical with those found as above, and all the Log. Secants are taken from the *same* page.

NOTES.

I The H.A. found as above is P.M. time if the Sun be west of Meridian, or what it wants of 24 hours if east. A.M. time may also be taken from the right-hand side of the Table of log. haversines. The above methods are equally applicable to Stars.

II. THE DEGREE OF DEPENDENCE.

The error in the Time arising from using only four places of decimals in the logs. may be easily found as follows :—

When taking out the H.A. from Table VI., look among the parts for seconds in the same line for the number 10, or the nearest number to 10, and take out the seconds corresponding to it. These divided by 10 will give the error due to an error of 1 in the fourth figure of the log. vers. H.A.

Thus for 2h. 20m. 10 gives 10 sec., ∴ the error is 1 sec.
„ „ 3h. 20m. 10 gives 15 sec., ∴ the error is 1·5 sec., &c.

As the final figure in each log. is between 0 and ·5 either in excess or defect of what it ought to be, the errors will generally be found to cancel each other, and as a matter of fact will, in the aggregate, seldom exceed unity; and, as will appear from above, the resulting error in the H.A. will therefore rarely exceed 2 seconds of time or half-a-minute of longitude.

III. THE ALTITUDE-AZIMUTH.

(By the Secant Method.)

Lat.	40° 23′	·1182	...	sec.
Alt.	29 18	·0595	...	„
P.D.	79 53			
		·1777	(A.)	
	149 34			
½ Sum	74 47	·5809	...	sec.
*Diff.	5 6	·0018	...	„
		·5827	(B.)	
	A—B	9·5950		
	½-log. Hav.	4·7975		
	Az. :	S. 77° 42′ E.		

The above short method will be useful when the Azimuth is required to a greater degree of exactness than can be found by the ordinary tables, and is independent of the time.

* To find the diff. subtract the half sum from the Polar distance or the Polar distance from the half sum if the latter is the greater.

EXPLANATION OF TABLES IV. TO XI.

TABLE IV. Required the Log. Sec. of 30° 25′.

Log. sec. 30° 20′ = ·0639, and the parts for 5′ are 4, adding which we have ·0643 for the required log. sec. Conversely: To find the degrees corresponding to log. sec. ·0643. The log. sec. next less is ·0639, which gives 30° 20′, and the diff., 4, gives 5′.

∴ The arc required is 30° 25′.

When the parts for 1′ exceed 1 those for $\frac{1}{2}'$, $\frac{1}{4}'$ may be found by dividing the parts for 1′ by 2 or 4 as the case may be. When less than 1 they may be disregarded.

TABLES V. and VII. are used in the same way, except, that as the cosines decrease the parts for minutes must be subtracted instead of added.

TABLE VI. To take out the time for log. hav. 9·1352. The log next less is 9·1329, which gives 2 h. 53 m., and the remainder is 23, which looked for in the same line gives 30 sec. at the top. ∴ The time is 2 h. 53 m. 30 sec.

Conversely.—To find the log. hav. of 2 h. 53 m. 30 sec., 2 h. 53 m. gives 9·1329, and the parts for 30 secs. are 23, adding which we have 9·1352, and so on. When the remainder is not found exactly among the parts take the seconds corresponding to the nearest or the mean as the case may be. Thus, if, in the preceding case, the remainder had been 25, the mean of the seconds would be 32·5, or 32 to the nearest second. If it had been 24 we might have taken 30 sec., or, if 26, 35 sec., and so on. Again, suppose in the above case the remainder to be 38, we see that the next less is 35, which gives 45 sec., and remainder 3. Now in the same line 31 gives 40. ∴ 3·1 gives 4 sec.; adding this, the seconds for remainder 38 will be 49, and so on.

TABLE VII. It will be seen that in the last two or three lines the log. cosines decrease very rapidly, so that it will be better to find the parts by taking the diff. of the two log. cosines and dividing by 5. Example: Find log. cos. 88° 8′:—

Here 88° 5′ =	3·5243			3·5243
And 88° 10′ =	3·5050		38·6 × 3′	115
5)	193		Required log. =	3·5128
Pts. for 1′ =	38·6			

This is seldom required in actual practice.

TABLE VIII.—TRAVERSE TABLE.

This Table is intended to supply the place of the Traverse Table as far as it is required in the methods contained in this book.

Ex.: Required the diff. lat. and dep. made by a ship sailing S. 35°, W. 20′.

Here co. 35° and dist. 1′ give ·82 d. lat. and ·57 dep.

∴ Diff. lat. = 20 × ·82 = 16·4, and dep. = 20 × ·57 = 11·4.

Diff. of longitude corresponding to dep. may be found by dividing the Dep. by the D. Lat. which corresponds to the degree of latitude taken out as a course.

Ex.: Given Lat. 42° and Dep. 12′, find D. Long.

Here Lat. 42° as course gives D. Lat. ·74.

And 12 ÷ ·74 = 1200 ÷ 74 = 16′ D. Long.

Conversely, D. Long. may be converted into Dep. by multiplying by the D. Lat. taken out as above.*

Table IX. requires no explanation.

Table X.—When entering this table with degrees the corresponding time will be hours and minutes, and when with minutes it will be minutes and seconds of time.

Ex. I:

Convert 38° 25′ into time.

	H. M.
Here 38° =	2 32
And 25′ =	1 40
∴ 38° 25′ =	2 33 40

Ex. II:

Convert 53° 32′ 45″ into time.

	H. M.
Here 53° =	3 32
32′ =	2 8
45″ =	3
∴ 53° 32′ 45″ =	3 34 11

The above is easily done by inspection.

Conversely, Convert 2h. 33m. 40s. into arc, and convert 3h. 34m. 11s. into arc.

	H. M.		
Here	2 32	=	38°
	1 40	=	25′
∴	2 33 40	=	38 25

	H. M.		
Here	3 32	=	53°
	2 8	=	32′
	3	=	45″
∴	3 34 11	=	53 32 45

TABLE XI.—FOR CORRECTING THE DECLINATION AND EQN. OF TIME.

Ex. I.: G.Time 7h. 30m., after Noon, H.D. 37′+

H.D. 37″ and 7h.	=	4′ 19″
Parts for 30m.	=	18″
Correction	=	4 37+

Ex. II.: Gr. Time 4h. 45m. before Noon, H.D. 43″+

H.D. 43° and 4h.	=	2′ 52″
Parts for 45m.	=	32
∴ Correction	=	3 24 −

N.B.—If the declination is required in an observation taken after noon it is corrected *on*, and if before noon, *back*, which accounts for the sign being reversed in Ex. II.

TO CORRECT THE EQUATION OF TIME.

Ex. I.: G.Time, after Noon, 7h. 50m. H.D. ·25s. +

H.D. 25″ and 7·50 = 3′ 15″ = 195″
∴ Dividing each by 100
We have ·25s. = 1·95s. +

Ex. II.: G.Time, 3h. 40m., before Noon, H.D. ·88s. −

H.D. and 44 and 3 40 = 2′41″ = 161″
∴ ·44 = 1·61s. (Dividing by 100)
And ·88 = 3·22s. +

The sign of the A.M. correction is changed, as in the case of the Declination.

* This multiplication and division may be performed by Table IIA.

MULTIPLICATION AND DIVISION BY TABLES I. & II.

Look for the multiplicand in the first column and the multiplier in the second top line, and note the degrees of bearing and latitude adjacent to each. This latitude and bearing will then give the product to two places of decimals.

Example I.—Multiply ·29 by 1·56.

·29 = bearing 74°, and 1·56 = latitude 50°,

∴ latitude 50° and bearing 74° = ·44.

If the number had been 29, the result would have been 44; or if 2·9, 4·4, and so on.

Example II.—Multiply ·31 by 1·56.

·31 = bearing 73°, and 1·56 = latitude 50°.

Latitude 50° and bearing 73° = ·47.

When the numbers are not found exactly, take the mean.

Example III.—Multiply ·38 by 1·59.

Here ·38 = bearing 69°, and 1·59 = latitude 51°.

Latitude 51° and bearing 69° = ·61, &c.

DIVISION.

Is performed in exactly the reverse way.

Example I.—Divide ·44 by 1·56.

As before, 1·56 = latitude 50°.

Latitude 50° and ·44, same column, = bearing 74° = ·29.

If the number had been 44, the quotient would be 29, by shifting the points as in multiplication.

Example II.—Divide ·58 by 1·59.*

Here 1·59 = latitude 51°,

And latitude 51° and ·58, same column, = bearing 70° = ·36.

If the exact numbers are not found, take the mean. Table I. is used in the same way, except that we use time instead of bearing; and we use this Table in preference to Table II. when both numbers consist of two figures only.

* If the divisor is too large for the scope of the Table, divide both it and the dividend by 2 or 3. Thus if we have to divide 1·16 by 3·18, we have ·58 ÷ 1·59 or ·36 to the nearest whole number, &c.

ALTITUDE-AZIMUTH TABLE.*

To be used in combination with the Traverse Table.

LATITUDE.						ALTITUDE.					
Lat.	A	B	Lat.	A	B	Alt.	C	Alt.	C	Alt.	C
1°	100	2	33°	119	65	1°	100	34°	83	66°	41
2	100	3	34	121	67	2	100	35	82	67	39
3	100	5	35	122	70	3	100	36	81	68	37
4	100	7	36	124	73	4	100	37	80	69	36
5	100	9	37	125	75	5	100	38	79	70	34
6	101	11	38	127	78	6	99	39	78	71	33
7	101	12	39	129	81	7	99	40	77	72	31
8	101	14	40	131	84	8	99	41	75	73	29
9	101	16	41	133	87	9	99	42	74	74	28
10	101	18	42	135	90	10	98	43	73	75	26
11	101	19	43	137	93	11	98	44	72	76	24
12	102	21	44	139	97	12	98	45	71	77	22
13	103	23	45	141	100	13	97	46	69	78	21
14	103	25	46	144	104	14	97	47	68	79	19
15	104	27	47	147	107	15	97	48	67	80	17
16	104	29	48	149	111	16	96	49	66	81	16
17	105	31	49	152	115	17	96	50	64	82	14
18	105	32	50	156	119	18	95	51	63	83	12
19	106	34	51	158	123	19	95	52	62	84	10
20	106	36	52	162	128	20	94	53	60	85	9
21	107	38	53	166	133	21	93	54	59	86	7
22	108	40	54	170	138	22	93	55	57	87	5
23	109	42	55	174	143	23	92	56	56	89	3
24	109	45	56	179	148	24	91	57	54	89	2
25	110	47	57	184	154	25	91	58	53	90	0
26	111	49	58	189	160	26	90	59	51		
27	112	51	59	194	166	27	89	60	50		
28	113	53	60	200	173	28	88	61	48		
29	114	55	61	206	180	29	87	62	47		
30	115	58	62	213	188	30	87	63	45		
31	117	60	63	220	196	31	86	64	44		
32	118	62	64	228	205	32	85	65	42		
33	119	65	65	237	215	33	84	66	41		
34	121	67	66	246	225	34	83	67	39		
Lat.	A	B	Lat.	A	B	Alt.	C	Alt.	C	Alt.	C
LATITUDE.						ALTITUDE.					

To Find the Azimuth.

Take out A and B for lat. and C for alt., and with A and B as dist. and dec. and alt. as course find dep. (Trav. Tab.). Take the diff. or sum of these deps. according as lat. and dec. are of the same or contrary names; the course corresponding to C as dist., and this sum or diff. will be the Azimuth or Bearing from South in North lat. and *vice versâ*.

Exception :—If the first dep. is greater than the second, when lat. and dec. are of the same name, reckon the Bearing from North in North lat. and from South in South lat.

* Reprinted from earlier editions of this work, and here inserted for the convenience of those accustomed to this method of obtaining the Azimuth.

EXAMPLES.

1. Lat. 50° N., Alt. 30° W'ly, Dec. 20° N.

We have A. 156, B. 119, C. 87.

Dist.		Co. Dep.
156	and	20° = 53·4
119	,,	30° = 59·5

co.
87 and d. lat. 6·1 = 86°

Ans. Azimuth S. 86° W.

2. Lat. 40° N., Alt. 12° E'ly Dec. 8° S.

By Tab. A. 131, B. 84, C. 98.

Dist.		Co. Dep.
131	and	8° = 18·2
84	,,	12° = 17·5

co.
98 and d. lat. 35·7 = 68½°

Ans. Azimuth S. 68½° E.

3. Lat. 52° N., Alt. 7° E'ly, Dec. 15° N.

A. 162, B. 128, C. 99.

Dist.		Co. Dep.	
162	and	15° = 41·9	(Gr.)
128	,,	7° = 15·6	

co.
99 and d. lat. 26·3 = 74½°

Ans. Azimuth N 74½° E.

4. Lat. 45° N., Alt. 31° W'ly Dec. 15° N.

A. 141, B. 100, C. 86.

Dist.		Co. Dep.
141	and	15° = 36·5
100	,,	31° = 51·5

co.
86 and d. lat. 15·0 = 80°

Ans. Azimuth S. 80° W.

Example 3 shows the exceptional case, the first dep. being greater than the second.

The above results are the same as by actual calculation, within a quarter of a degree or so.

To find the approximate Ship Time.

Transpose altitude and declination, and proceed as in finding the Azimuth, observing to take out C for the declination instead of altitude.

Example 1 (*above*).

A. 156, B. 119, C. 94.

Dist.		Co. Dep.
156	and	30° = 78·0
119	,,	20° = 40·7*

co.
94 and d. lat. 37·3 = 66½°

Ans. H.A. 4h. 26m.

Example 2 (*above*)

A. 131, B. 84, C. 99.

Dist.		Co. Dep.
131	and	12° = 27·2
84	,,	8° = 11·7

co.
99 and d. lat. 38·9 = 67°

Ans. H.A. 4h. 28m.

Example 1 gives the H.A. within 1m. 11s., and Example 2 within 19 sec., thus affording a ready way of correcting the ship's clock when rapidly changing the longitude.

The observations should not be taken when the sun is within two or three points of the Meridian.

---

* If the second dep. is greater than the first, when lat. and dec. are of the *same* name, subtract the H.A. from 12 hours.

TO IDENTIFY AN UNKNOWN BRIGHT STAR.

If, on a cloudy night, a bright star appeared for a short time through an opening in the clouds, and we wished to ascertain its name, we could do so as follows :—

(1) Observe the star's altitude, and bearing by azimuth compass, to which apply the usual corrections. (2) Convert the bearing into time, and consider it as an H.A.; also consider the altitude as declination of the same name as the latitude. (3) With the latitude, this hour-angle, and declination, find the bearing by Tables I. and II.

This will be the star's hour-angle if this bearing is of the same name as the latitude, or what it wants of 12 hours if of contrary name. Then the Meridian R.A. $\pm$ star's H.A., according as the star is east or west of Meridian, will be the star's R.A., and the star whose R.A. agrees with this will be the body observed.

Example I.

June 2nd, at 8 p.m., in lat. 32° N., a star whose altitude was 21° bore N. 56° E. (true). Required—its name.

	h. m.				h. m.
Bearing 56° =	3 44	...	Tab. X.	S.M.T. ...	8 0
Lat. 32° and	3 44 =	·42 S.	Tab. I.	Sid. Time	4 40
Dec. 21° ,,	3 44 =	·47 N.	,,		
				Mer. R.A.	12 40
By Tab. II. Lat. 32° and		·05 N.	= N. 88° E. =	* H.A.	5 52 E.
				Star's R.A.	18 32*

Now as the R.A. of Vega is 18h. 34m., it shows that this must have been the star observed.

Example II.

August 22nd, at 7.13 p.m., in lat. 30° N., a star whose altitude was 20° bore S. 63½° W. (true). Find its name.

					h. m.
Bearing 63½° =	4·14 ...	Tab. X.		S.M.T.	7 13
30°	4·14	·29 N.†		Sid. Time	10 2
20°	4·14	·40 N.			
					17 15
30°	and	·69 N. = N. 59° W. =	*H.A.	...	3 56 W.
				Star's R.A.	13 19

As Spica has the same R.A., nearly, it was the star observed.

ζ^1 Ursæ Majoris having the same R.A., any uncertainty may be removed by finding the true bearing, using lat. 30°, H.A. 3·56 and the declination of either star, then, if this bearing agrees with the observed bearing, it shows that star to be the right one, but if not, it must be the other. The same remark applies to Capella and Rigel, the R.A. of which is 5·10.

---

* If the sum of the Mer. R.A. and Star's H.A. exceed 24 hrs., reject 24 hrs.; and if the H.A. (West) exceed the Mer. R.A. increase the latter by 24 hrs.

† As the angle between N. and S. 63½° W., used as an H.A., exceeds 90°, or 6 hrs., we mark both numbers with the same name as the latitude; *vide* exceptional case, p. 17.

TABLES FOR FINDING THE STARS.

SIDEREAL TIME.

FOUR MINUTES ARE TO BE ADDED FOR EACH INTERMEDIATE DAY.

DAY.	JAN.	FEB.	MAR.	APL.	MAY.	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
1	18 39	20 41	22 36	0 38	2 36	4 38	6 37	8 39	10 39	12 39	14 41	16 40
6	18 59	21 1	22 55	0 57	2 56	4 58	6 56	8 59	10 58	12 59	15 1	16 59
11	19 18	21 21	23 15	1 17	3 15	5 18	7 16	9 18	11 18	13 19	15 21	17 19
16	19 38	21 40	23 35	1 37	3 35	5 37	7 36	9 38	11 38	13 38	15 41	17 39
21	19 58	22 0	23 54	1 57	3 55	5 57	7 55	9 58	11 58	13 58	16 0	17 59
26	20 18	22 20	0 14	2 16	4 15	6 17	8 15	10 17	12 17	14 18	16 20	18 18

LIST OF PRINCIPAL BRIGHT STARS.

NAME.	R.A.	DEC.	NAME.	R.A.	DEC.
	H. M.	° ′		H. M.	° ′
αAndromedæ...	0 4	28·35N	γCrucis	12 26	56·36S
αCassiopeiæ	0 35	56· 2N	βCrucis	12 42	59·11S
αUrsæ Min. (Polaris) ...	1 26	88·49N	αUrsæ Majoris	12 50	56·28N
αEridani	1 34	57·42S	ζ¹Ursæ Majoris	13 20	55·24N
αArietis	2 2	23· 2N	Spica	13 20	10·41S
αPersei	3 18	49·32N	ηUrsæ Majoris	13 44	49·46N
Aldebaran	4 31	16·19N	βCentauri	13 57	59·56S
Capella	5 10	45·54N	Arcturus	14 11	19·40N
Rigel	5 10	8·18S	α²Centauri	14 33	60·27S
αColumbæ	5 36	34· 7S	αCoronæ	15 31	27· 1N
αOrionis...	5 50	7·23N	Antares	16 24	26·14S
βAurigæ	5 53	44·56N	αTriangulus Aust.	16 39	68·51S
Canopus...	6 22	52·39S	αScorpii	17 27	37· 2S
Sirius	6 41	16·35S	αOphiuchi	17 31	12·38N
εCanis Majoris	6 55	28·51S	εSagittarii	18 18	34·26S
δCanis Minoris	7 5	26·15S	Vega...	18 34	38·42N
Castor	7 29	32· 5N	δSagittarii	18 50	26·25S
Procyon	7 34	5·28N	αAquilæ	19 46	8·37N
Pollux	7 40	28·15N	αPavonis	20 18	57· 2S
γArgûs	8 7	47· 4S	αCygni	20 38	44·57N
εArgûs	8 21	59·13S	αGruis	22 2	49·24N
αHydræ	9 23	8·16S	βGruis	22 37	47·22S
Regulus	10 3	12·25N	αPiscis Australis (or Fomalhaut)	22 53	30· 7S
αUrsæ Majoris	10 58	62·15N	Markab	23 0	14·43N
α¹Crucis	12 21	62·35S			

NOTE: Meridian Right-Ascension = Ship Mean Time + Sidereal Time.

TO FIND THE PRINCIPAL STARS ABOVE THE HORIZON AT ANY GIVEN TIME.

Example.

What stars are above the horizon at a place on the Equator at 8 p.m. on July 23rd?

	h. m.			
S.M.T. July 23	8 0			
Sid. Time ,,	8 3			
Mer. R.A.	16 3	...	16 3	
	6 0	...	6 0	
Star's R.A.	10 3	W	22 3	E

Then all stars whose R.A.'s lie between 10·3 and 22·3 will be above the horizon at 8 p.m. Those whose R.A. is between 10·3 and 16·3 will be West of Meridian, and those between 16·3 and 22·3 East. Further North more stars of North Decln. will be visible and fewer of South Decln., and *vice versâ*.

ON FINDING THE STARS.

By Tables, page 51.

1. To find what Bright Stars will pass the Meridian of a place on May 11th, between 8.0 and 12.0 p.m.

	h. m.		h. m.
S.M.T.	8 0	and	12 0
Sid. Time, May 11	3 15	,,	3 15
Meridian R.A.	11 15		15 15

Then the stars whose R.A.'s lie between 11·15 and 15·15 will pass the Meridian between 8.0 and 12.0 p.m., viz.: all stars between α^1 Crucis and α^2 Centauri.

2. To find at what time Arcturus will pass the Meridian on the same date, viz.: May 11th.

	h. m.
R.A. of Arcturus	14 11
Sid. Time, May 11	3 15
Time of Mer. Pass.	10 56

If the latitude is 50°·0'N. find the Mer.-Alt. of Arcturus.

Lat.	50°·0′	N.
*Dec.	19 ·40	N.
M.Z.D.	30 ·20	
Mer. Alt.	59 ·40	

So that if we set the index of our sextant at 59°·40′ and look towards the South point of the horizon at 10·56 we shall have no difficulty in finding the star, and can then screw in the telescope and complete the observation.

If a star's declination is greater than the latitude and of the same name it will pass the Meridian between the Zenith and the Elevated Pole. If therefore both lat. and dec. are North we should have to look towards the North point of the horizon.

If a star's Polar Dist. is less than the latitude it is a circumpolar star, and if its declin. is greater than the co-lat, it will not rise when they are of contrary names.

3. To find what stars are above the horizon and within 4 hours of the Meridian, East and West, at 8.0 p.m. July 23rd, and therefore suitable for time observations.

	h. m.
Ship M.T.	8 0
Sid. Time, July 23	8 3
Mer. R.A.	16 3

Subtracting and adding 4 hours we have 12·3 and 20·3.

∴ Stars whose R.A.'s lie between these times are within 4 hours of the Meridian at 8.0 p.m.

Those furthest from the Meridian are most suitable for time provided that their declination does not exceed 30° or so. Thus Spica is the only suitable star West of Meridian, and δ Sagittarii and α Aquilæ East of Meridian.

Note.—Stars whose R.A. is less than the Mer. R.A. are West of Mer. and those greater East of Mer.

WHERE TO LOOK FOR A GIVEN STAR AT ANY TIME.

Example.

Being in lat. 40° N., in what part of the heavens shall I look for Capella on May 1st, at 8.0 p.m., its R.A. and Dec. being 5h. 10m. and 46° N.?

(1) Find its Bearing by Az. Rule.

S.M. Time, May 1st	8 ·0				
Sid. Time „	2·36	Lat. 40°	5·26	·13 S.	
		Dec. 46°		1·05 N.	
Mer. R.A ...	... 10·36				
Star's R.A.	... 5·10	Lat. 40°	and	·92 N.	= N.55° W.
Star's H.A. ...	5·26	∴ It bears N. 55° W.			

(2) Find its Altitude.

To do this interchange Az. and H.A. and proceed as follows:—

Az. 55° = 3h. 40m., H.A. 5·26 = Az. 81½°.
Lat. 40° and 3·40 = ·59 Tab. I.
Lat. 40° and 81½ = ·19 „ II.

(H.A. for Dec.) 3·40 and ·78 = 32° Alt.

The numbers are to be added unless the H.A. is greater than 6 hours or the Bearing is of a contrary name to the latitude, in which case we take the difference.

To find the altitude look for the H.A. in the right-hand or Declination H.A. column, and for ·78 in the same line, the altitude will be the degrees at the top of the column in which ·78 is found.

If then we put alt. 32° on the sextant and look towards that point of the horizon which bears N. 55° W., we shall have no difficulty in identifying the star.

TO IDENTIFY A STAR BY ITS MER. ALTITUDE.

Find the star's Z.D. when on the Meridian; then if this is less than the latitude the star and the observer are on the same side of the Equator, but if greater they are on opposite sides.

Example I.

In lat. 49°·10 N. a star's mer. alt. bearing south was 46°·20; find its name.

			° ′
Obs. Alt.	...	...	46·20 S.
„ Z.D.	...	...	43·40 S.
Lat. ...	...	...	49·10 N.
Dec. ...	...	...	5·30 N.*

As the dec. of Procyon was 5·28 N. it was the star observed.

Example II.

In the same latitude the mer. alt. of a star, bearing south, was 35°·24′; required, its name.

			° ′
Obs. Alt.	...	...	35·24 S.
„ Z.D.	...	...	54·36 S.
Lat. ...	...	...	46·20 N.
Dec. ...	...	...	8·16 S.

As this agrees with the dec. of αHydræ, it must have been the star required.

* When lat. and zen. dist. have the same name, their sum, if less than 90°, will be the dec.; but if greater than 90°, the sum subtracted from 180°.

TO FIND A STAR'S H.A. AT RISING AND SETTING.

Convert the degrees in the polar dist. into time and with this time and the latitude take out the Nr. from Tab. I. Look for this Nr. in the last column of Tab. II. and take out the Bearing.

This converted into time will be the star's H.A. at rising and setting if latitude and declination are of contrary names, or what it wants of 12 hours if of the same name.

Example I.	*Example* II.
Given: Lat. 35°N. Dec. 12°S.: to find the H.A. at rising or setting.	Given: Lat. 45°N. Dec. 15°N.: to find the rising and setting H.A.
Here P.D. 78° = 5h. 12m.	Here 75° = 5h. 0m.
By Tab. I. Lat. 35° and 5·12 = ·15.	Lat. 45° and 5·0 = ·27. Tab. I.
By Tab. II. ·15 = Bearing 82° = 5·28	·27 = 74° = 4h. 56m. ,, II.
∴ H.A. at rising or setting = 5h.28m.	∴ H.A. = 12h.—4·56 = 7h. 4m.

In Example II. the H.A. is subtracted from 12 hrs. as Lat. and Dec. are of the same name.

TO FIND AT WHAT TIMES A STAR WILL RISE, CULMINATE AND SET.

Find its H.A. at rising or setting as above, and the time it passes the Meridian, to which apply the H.A. at rising, etc.

Subtracting for the time of rising and adding for the time of setting.

Example I.

At what times will Arcturus rise, culminate and set on Oct. 3rd in lat 30° N.? (*R.A. 14h. 11m. Dec. 20° N.)

Here P.D. 70° = 4h. 40m.	*R.A.	14·11		
Lat. 30° and 4·40 = ·21 Tab. I.	—Sid. Time	12·47		
And ·21 = Bearing 78° = 5·12 ,, II.	Mer. Pass	1.24 p.m.	...	1.24 p.m.
∴ H.A. = 12h. − 5·12 = 6·48	H.A.	6.48	...	6.48.
	Setting	8.12 p.m.	Rising	6.36 a.m.

Answer: Arcturus rises at 6.36 a.m., culminates at 1.24 p.m., sets at 8.12 p.m.

Example II.

At what times will Jupiter rise, culminate and set on Feb. 16th in lat. 40° N.? (*R.A. 23h. 50m., Dec. 15° S.)

Here P.D. 75° = 5h. 0m.	*R.A.	23·50		
Lat. 40° and 5·0 = ·22	—Sid. Tim	21·40		
·22 = 78° = 5·12	Mer. Pass	2.10 p.m.	...	2.10 p.m.
	H.A.	5.12	...	5.12
	Sets	7.22 p.m.	Rises	8.58 a.m.

∴ Jupiter rises at 8.58 a.m., culminates at 2.10 p.m., sets at 7.22 p.m.

APPLICATION OF TABLES I. AND II. TO GREAT CIRCLE SAILING.

In the Time Azimuth two sides of a spherical triangle and the included angle are given to find the azimuth, and in great circle sailing the same parts are given to find the course. It is evident therefore that the operation is precisely the same. Thus, if in Ex. I., p. 17, we take lat. 40° N. as the latitude from, and dec. 20° N. as lat. 20° N., the latitude to, and the H.A. 3h. 48m. as diff. long., and work it out in the same way, we shall have as course S. 85½ E.

If the latitude of either place is greater than 60°, we must proceed as in Ex. I., p. 22 ; which example might be expressed as follows :—

Given : Lat. A. 76° N., Lat. B. 12° N., Diff. long. 51° E. :
To find the Course from A. to B. :
By Tab. (i.), p. 35, Lat. 76° = Lat. 53° and Divisor 3.
By Tab. I., Lat. 53° N. and H.A. 3h. 24m. (= 51°) = 1′·07 S.
Also by same table Dec. 12° N. and H.A. 3h. 24m. = ·27 N.
Which latter divided by 3 = ·09′ N.

Hence we have	...		1′·07 S.
And ...	...	...	·09 N.
∴ The diff.	...	... =	·98 S.

Again by Tab. (ii.), p. 35, Lat. 76° = Lat. 44°.
∴ By Tab. II., Lat. 44° and ·98′ S. = S. 55° E., the Course required.

To find the approximate distance.

Take from the column (a') the numbers for the co-lat. B, and diff. long. and multiply them together by the Table. Look for the result in the column at the top of which is the degree denoting the course ; the corresponding bearing will be the distance required, in degrees. Thus in the above example :—

$$\left.\begin{array}{l}\text{Co-lat. B or } 78° = 1'{\cdot}02 \\ \text{Diff. long.} \quad 51° = 1'{\cdot}29\end{array}\right\} (a') \text{ column.}$$

And 1′·02 × 1′·29 = 1′·31 by Tab. II.
Lastly, Course 55°, and 1′·31 = Bearing 53°. ,,
∴ The Dist. = 53° × 60, or 3,180 miles.

THE ALTITUDE-AZIMUTH BY TABLES I. AND II.

N.B.—The degrees at the top of the Tables serve both for latitude and altitude, and those in the Bearing Column, Tab. II., *p. 29, both for zenith dist. and polar dist.*

Rule.—From the last column of Tab. II., p. 29, take out the numbers corresponding to the zenith dist. and polar dist., which denote by A. and B.

With the lat. and A. take out the Nr. from Tab. I., and with the lat. and B. take out the Nr. from Tab. II., marking the first Nr. with the *opposite* name to the latitude, and the second with the *same* name as the declination.

When both names are alike, take their *sum* with the common name; and when different, their difference, with the name of the greater.

This shows the point from which to reckon the azimuth.

To find the Azimuth.

With the altitude as latitude and this sum or difference, take out the Nr. from Tab. II. and look for it in the last column of Tab. II., p. 29, when in the *same* line will be found the bearing, or azimuth—which mark as above directed.

Example I.

Lat. 50° N., Z.D. 60°, West of Mer., P.D. 70° (N).
Here A = ·50, B = ·34
Lat. 50° and ·50 = ·59 S. Tab. I.
Lat. 50° and ·34 = ·52 N. Tab. II.

Alt. 30° and ·07 S = ·08 S. Tab. II.
∴ Azimuth = S. 86° W.

By calculation this would be 85° 47′ W.

Example II.

Lat. 52° N., Z.D. 83°, E. of Mer., P.D. 75° (N).
Here A = ·12, B = ·26
Lat. 52° and ·12 = ·16 S. Tab. I.
Lat. 52° and ·26 = ·43 N. Tab. II.

Alt. 7° and ·27 N. = ·27 N. Tab. II.
∴ Azimuth = N. 74° E.

By calculation this would be 74° 33′.

Example III.

Lat. 40° N., Z.D. 78°, E. of Mer., P.D. 82° (S).
A ·21, B ·14
Lat. 40° × ·21 = ·17 S. Tab. I.
Lat. 40° × ·14 = ·18 S. Tab. II.

Alt. 12° and ·35 S. = ·36. Tab. II.
∴ Azimuth = S. 68° E.

By calculation this would be 68° 39′.

After a little practice this may be abbreviated as follows :—

·17 S.
·18 S.

Alt. 12° & ·35 S. = ·36 = S. 68° E.

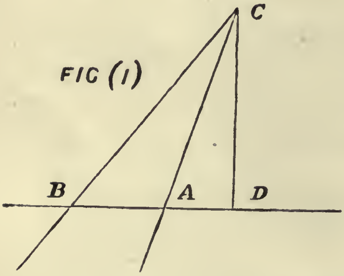
THE CONSTRUCTION OF TABLE II.*

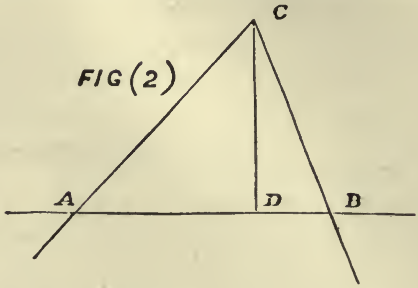
The first column (for lat. 0°) consists of natural co-tangents; the line of figures at the top 1·00, &c., to 2·00 are natural secants of the degrees above them, and the single line at the bottom natural tangents of the degrees at the top of the column. The other columns are the products of the natural co-tangents at the side of the Table and the natural secants at the top, and as both these are natural numbers the Table may be said to give the result of the multiplication of any two natural numbers corresponding to those given in the first column and at the top to two places of decimals. Thus to multiply 1·19 by 1·56 we have by the Table 1·85, which, to two places of decimals, is the same as by actual multiplication. Conversely 1·85 ÷ 1·56 = 1·19, which also is the same result as that obtained by actual division.

The numbers at the bottom of the Table are the natural tangents of 0°–60°. Those in the Dep. or *d* column are the natural co-secants of 10°–90°; and in the last column on the right, the natural cosines of the same. If the natural tangent of an angle greater than 60° be required, take the nat. co-tan. of the complement; and if a natural secant, take the natural co-secant of the complement.

* This Table was first published in the 4th Edition of this little book in 1874. It was subsequently, by the Author's permission, inserted in Lecky's "Wrinkles," Inman's Nautical Tables, &c. In the former, and in The General Utility Tables, by the same Author, it now appears in an expanded form, as Table (C).

EXPLANATION OF THE DOUBLE CHRONOMETER RULE.





Let C be the true zenith of the observer, CA., CB small portions of circles of equal altitude, BD a small portion of a parallel of latitude by D.R., CD a perpendicular from C on BA, or BA produced. (Fig. (1) is for observations taken on the same side of the meridian, fig. (2) for those taken on opposite sides).*

Then the first observation worked with the D.R. lat. will place the ship at A, the second will place her at B. Therefore AB is the discrepancy (in dep.) between the two positions. Also CAD is equal to the azimuth at the first observation, and CBD is equal to that at the second.

In fig. (1)

$$\begin{aligned} AB &= BD - AD \\ &= CD \text{ Cot. } B - CD \text{ Cot. } A \\ &= CD (\text{Cot. } B - \text{Cot. } A) \end{aligned}$$

$$\therefore CD = \frac{AB}{\text{Cot. } B - \text{Cot. } A}$$

$$= \frac{AB \text{ Sec. } l}{\text{Cot. } B \text{ Sec. } l - \text{Cot. } A \text{ Sec. } l}$$

$$= \frac{\text{Diff. long.}}{\text{Cot. } B \text{ Sec. } l - \text{Cot. } A \text{ Sec. } l}$$

Similarly in fig. (2)

$$CD = \frac{\text{Diff. long.}}{\text{Cot. } B \text{ Sec. } l + \text{Cot. } A \text{ Sec. } l}$$

The values of cot. B, sec. l and cot. A sec. l are taken from Tab. II., and designated as (a) and (b). $\therefore$ Corr. for lat. $= \dfrac{\text{Diff. long.}}{(b) \mp (a)}$, taking the upper or lower sign according as the bearings are in the same, or adjacent quadrants.

* These triangles, being supposed to be very small, may be treated as plane triangles, right-angled at D.

The corrections for the two longitudes will be AD and BD expressed in diff. long.

or, AD sec. l, and BD sec. l.

But AD = CD cot. A, and BD = CD cot. B.

∴ The corrections are CD cot. A sec. l, and CD cot. B sec. l;

or, corr. for lat. × (a), and corr. for lat. × (b),

and it is evident by fig. (1) that when the observations are in the same quadrant, both corrections must be allowed in the same direction; but when in adjacent quadrants, they must be allowed in opposite directions, as in fig. (2), to make the two longitudes agree.

It will also be seen, by fig. (1), that if the sun bore S.E[ly.] and the correction for lat. were North, that for long. would be East; and by fig. (2), if the sun bore S.W[ly.] and the corr. for lat. were North, that for long. would be West.

Hence the Rule on pp. 7 and 8 :—

$$\frac{\text{S. E.}}{\text{N. W.}} \qquad \frac{\text{S. W.}}{\text{N. E.}}$$

THE TIME AZIMUTH.

In a spherical triangle ZPS, where PZ = 90° − l, PS = 90° ∓ d, ZPS = h, and PZS = A, the azimuth, it may be shown that—

	Cot. PS sin. PZ	= cot. A. sin. ZPS	+ cos. PZ cos. ZPS.
Or,	Cot. A. sin. ZPS.	= cot. PS. sin. PZ	− cos. PZ cos. ZPS.
∴	Cot. A. sin. h	= tan. d cos. l	− sin. l cos. h
Whence,	Cot. A. sec. l	= tan. d cosec. h	− tan. l cot. h
Or,	Cot. A. sec. l	= −tan. d cosec. h	− tan. l cot. h......(θ)

when latitude and declination are of opposite names.

To adapt this to Table I., which contains the products of natural tangents and natural co-tangents, we assume that cosec. h = cot. h'; then tan. d cosec. h = tan. d cot. h' which is a similar expression to the second term of the right-hand side of the equation (θ), and shows that both the numbers for the latitude and declination may be taken from the *same* table, and without any sacrifice of accuracy, while at the same time the table is applicable to all declinations from 0° to 58°, and may therefore be used, not only in finding the bearing of the sun, *but also of all stars within the above limits.*

Explanation of the Ex-Meridian.

In the spherical triangle ZPS, where ZP represents the co-latitude, PS the polar-distance, ZS the zenith-distance, and ZPS the hour-angle, (h), supposed to be very small, it may be shown by spherical trigonometry, that—

$$\text{Vers. } h = \frac{\cos.\ (l \sim d) - \cos.\ z}{\cos.\ l \cos.\ d.}$$

But $(l \sim d)$ = the mer. zen. dist. $= z'$, suppose,

$$\therefore \text{ Vers. } h = \frac{\cos.\ z' - \cos.\ z}{\cos.\ l \cos.\ d}$$

Or $\cos.\ l \cos.\ d \text{ Vers. } h = \cos.\ z' - \cos.\ z$

$$= 2 \sin.\ \frac{z+z'}{2} \sin.\ \frac{z-z'}{2} \ldots \text{(A)}$$

But, since the sun is supposed to be near the meridian,

$\frac{z+z'}{2} = z$, nearly; and $z - z'$ = the reduction, = C, suppose,

$$\therefore \text{ From (A), } 2.\ \cos.\ d \cos.\ l \text{ hav. } h = 2 \sin.\ z, \sin.\ \frac{C}{2} \ldots \text{ (B).}$$

But since $\frac{C}{2}$ is very small, we have, by using the circular measure,

$$\text{Sin.} \frac{C}{2} = \frac{\frac{C}{2}}{r} = \frac{C}{2r}$$

$$\therefore \text{ From (B), } \cos.\ d \cos.\ l \text{ hav. } h = \sin.\ z.\ \frac{C}{2r}$$

$$\therefore C = 2r \cos.\ d \cos.\ l \text{ cosec. } z \text{ hav. } h$$

$$= 2r \text{ hav. } h \cos.\ d \cos.\ l \text{ sec. alt.}$$

Where $r = 57° \ 28'$, or $3438'$. The upper part of the Table gives the values of cos. l sec. alt., or N.; and the lower part those of $2r$. hav. $h \times$ N.

A further correction (for the declination) may be applied when both the reduction and the declination are considerable.

Note.—The Table exhibits at a glance the values of the reduction corresponding to any given value of N, and therefore shows the error that would be produced by an error of 1 minute (or any other portion) of time, in the hour-angle, which is important as showing the degree of dependence that may be placed in a given observation.

To find by Table II. *the correction for the longitude for* 1′ *error in the altitude.*

Take from the last column but one of Table II. the nearest or mean bearing, and with this bearing and the given latitude take out the correction as before. This will be the correction for 1′ of altitude, which, when the observed altitude is too small, is allowed towards the East or West, according as the body observed is East or West of the meridian, and *vice versâ* when it is too large.

Thus for Lat. 40° and Bearing 74° we have 1′·35.
And for Lat. 40° and Bearing 54° 1′·61. In this case as 54° comes between 51° and 57° we take the mean of 1′·67 and 1′·55, the corrections given by them.

If we wish to correct the H.A.; we multiply the correction found as above by 4 to obtain seconds of time; then if the observed altitude is too small it will make the H.A. too great, and *vice versâ*, the correction must therefore be allowed accordingly.

Explanation of the Alt.-Azimuth Rule.

In a spherical triangle PZS, where PS represents the polar dist., ZS the zenith dist., PZ the co-lat., and PZS the azimuth, we have

$$\text{Cos. PZS} = \frac{\pm \text{Cos. PS} - \text{Cos. PZ Cos. ZS}}{\text{Sin. PZ Sin. ZS}}$$

$$\text{or Cos. A}\, z = \frac{\pm \text{Cos. } p - \text{Sin. } l \text{ Cos. } z}{\text{Cos. } l \text{ Cos. } a}$$

$$= \left\{ \pm \text{ Cos. } p \text{ sec. } l - \text{Cos. } z \text{ tan. } l \right\} \text{Sec.}$$

$$= \left\{ -\text{Cos. } z \text{ tan. } l \pm \text{ Cos. } p \text{ sec. } l \right\} \text{Sec. } a$$

Taking the upper or lower sign according as p is less or greater than 90°.

Let Cos. z=A, and Cos. p=B, then the above becomes

$$\left\{ -\text{A tan. lat.} \pm \text{ B Sec. lat.} \right\} \text{Sec. alt.}$$

Where A tan. lat. is given by Tab. I., and B Sec. lat. by Tab. II., Cos. z and Cos. p are taken from the last column of Tab. II., which column also contains the Nat-Cosine of the Azimuth.